SCIENCE IN THE MODERN WORLD

TREASURES FROM THE EARTH

BY

W. E. FLOOD

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Science in the Modern World.

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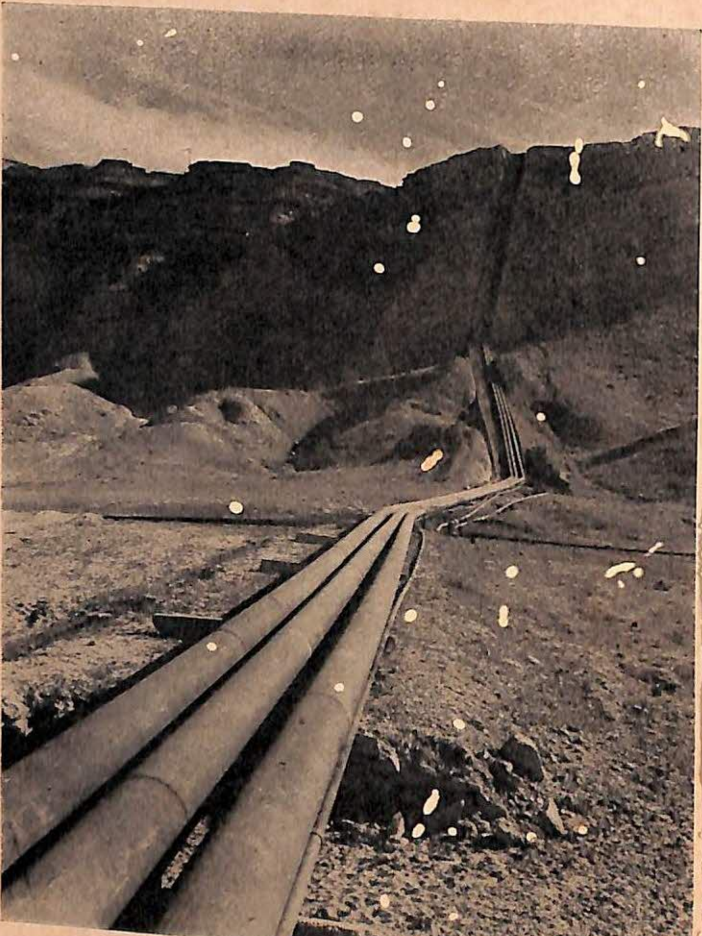

(By courtesy of Anglo-Iranian Oil Co. Ltd.)

Oil pipes crossing the hills in South Iran (Persia).

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TREASURES FROM THE EARTH

by

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With Diagrams
and Photographs

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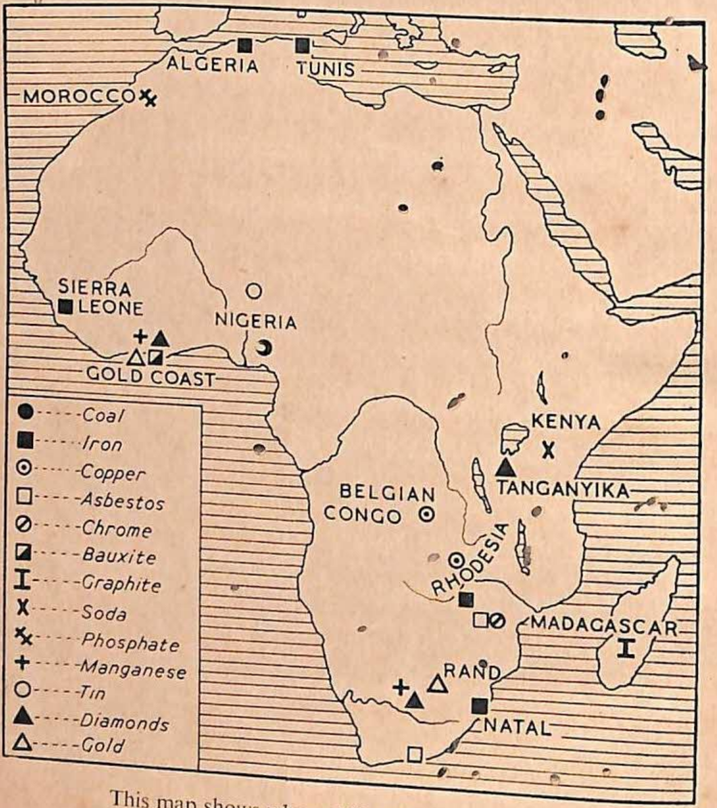


This map shows where different minerals are found in the continent of Africa.

FOREWORD

THIS BOOK TELLS YOU . . .

THE Earth on which we live is a great ball of rock. The water of the seas fills the lower hollows on its surface and we live on the higher, drier land. Round the Earth there is a thick layer of air. We cannot leave the Earth. We may go up into the air in an aeroplane but we cannot fly right away. We are born on the Earth, we live there, and we die there.

We must have certain things in order to live. These are food, drink, and air. But we also want many other things. We want houses to live in, clothes to wear, tools and machines to help us with our work, fires to cook our food and (at times) to keep us warm, ships, trains, cars and aeroplanes in which to travel. The materials from which these things are made must come, in some way, from the Earth. We cannot go anywhere else!

We get many useful materials from plants. Plants, of course, provide us with much of our food. Cotton, linen, and jute (from which sacks and boat-sails are made) come from plants. It would be almost impossible to make a list of all the uses of different kinds of wood. The list would include the making of paper and silk. Rubber, palm-oil (for soap), gum, and paint-oil are further examples of useful plant products.

Then we get other useful materials from animals. Some kinds of food, such as meat, eggs, milk, and butter, come from animals. Sheep provide us with wool from which we make cloth; we make leather from the skin of cattle and goats.

Animals eat plants, or eat other animals which have eaten plants, and plants obtain their food from the ground in which they grow and from the air around them. So we can say that all the materials which we get from plants and animals really come from the Earth.

There are other materials, however, which we obtain straight from the Earth. These are the materials which we find in, or make from, the rocks. We use such materials for many purposes. We use some for building houses, roads, and bridges. Others, such as coal and oil, are used for burning. Then there are the metals from which we make tools, machines, aeroplanes, engines and ships, and the substances from which we make glass and pots. We use other materials, such as gold and jewels, for ornaments; some, such as salt, we eat; some are used for making dyes, medicines, and fertilizers (for improving the soil in which plants grow). This list is far from complete but it helps to show you the many ways in which we use materials from the rocks.

This book tells the stories of some of the materials which we find in, or make from, the rocks. We cannot, in this little book, or indeed in one big book, tell the story of all the rock-materials. We have chosen some of the more important ones. A "treasure" is something which is of great value. As you read the stories of how we get these materials, and of their important uses, you will agree that they are Treasures from the Earth.

CHAPTER I

THE ROCKS OF THE EARTH'S CRUST

As we walk in the fields near our homes, or travel by train across the country, we see that the ground is made of different kinds of materials. We see the dark-coloured soil in which plants grow, the sand and mud by the side of a lake or river, and the harder ground of the hills and mountains. We see clay, chalk, building stone, and so on. In science all the materials of which the Earth is made are called rocks. We usually think of rock as a hard material like stone but in science the softer materials, like sand and clay, are also called rocks.

The Earth consists of many kinds of rocks. We know most about the rocks which are near the surface. We see them in places where the side of a hill has been cut away to make level ground for a road or railway. We see the rocks in the steep bank of a river and in the cliffs by the sea. Then men have seen the rocks in the mines from which coal (or other useful materials) is obtained. If we think of the Earth as a very big orange, the rocks which we see form part of the skin. This skin, which is 10–30 miles thick, is called the Earth's "crust." Below this crust there is a thick layer of heavier rock and in the middle, where it is very hot, the rocks are melted.

Scientists believe that, millions of years ago, the Earth broke away from the sun. It was very hot. As it cooled, the outer surface became solid first. The middle has not yet properly cooled. In some parts of the Earth great masses of melted rock have been pushed through holes and cracks in the crust out on to the surface. Mountains from which melted rocks are sent out are called volcanoes. Some volcanoes are still active, that is, they still send out melted rocks, but many are no longer active. A volcano may send out ashes and streams of melted rock; all send out great clouds of steam and hot gases. The melted rock cools and forms solid rock.

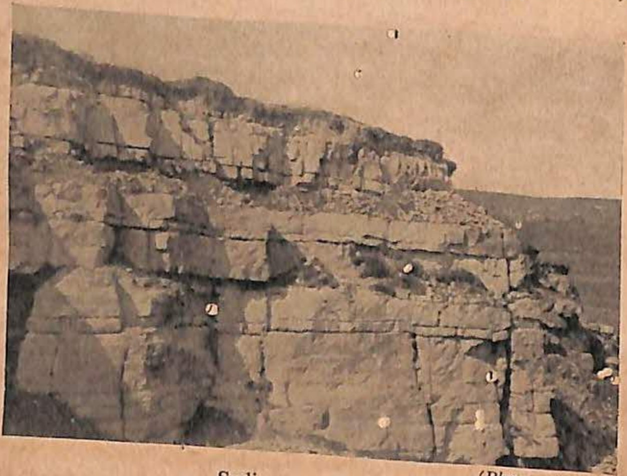
There is a well-known rock called granite. Perhaps you can find a piece near your home. It is a hard, rather heavy rock. It is often grey with white or pink spots but some kinds are mostly pink. If we look at a piece of granite carefully, we notice that it is made up of little bits of material. Some of these bits shine in the light. You know what sugar looks like. It consists of little pieces each with flat sides and sharp edges. We call such pieces crystals. Granite consists of two kinds of crystals stuck together by a kind of glassy solid. The biggest crystals, and some of the smaller ones, are white or pink. The material is called "felspar." Then there are smaller crystals shaped like thin flat plates. These may be white, brown, or black. The material is called "mica." The glass-like material is called "quartz."

Crystals are formed when melted rocks cool very slowly. If the melted rock which comes from a volcano cools quickly it forms a solid like dark-coloured glass, but if it cools slowly small crystals are often formed in it. Rocks like granite, which contain large crystals, were formed from melted rocks which did not escape through the surface. They cooled very slowly in cracks in the Earth's crust or deep below the surface. Afterwards, the rocks above them were gradually worn away. As rocks like granite have been formed from melted rocks, we can call them "fire-formed" rocks. The scientist calls them "igneous" rocks (Latin *ignis* = fire).

The Earth's crust at first consisted only of igneous rocks but during the millions of years since it was formed many changes have taken place. Wind, rain, ice, and rivers gradually break up and wear away the surface of the land. The little bits of rock are carried away, chiefly by the rivers, to lower parts and, especially, into the seas. The material may be carried out to sea but at last it falls to the bottom. After many years it forms a thick layer on the sea-bottom and is changed into hard rock.

Quartz crystals.

If you look at a hill-side which has been cut away or at a steep cliff by the sea, you often find that the rocks are in layers (see the picture on p. 4). Layers may be of different colours and may consist of different kinds of rock. Millions of years ago these rocks were layers on the bottom of some ancient sea. They were formed from bits of rock carried to the sea by rivers. Then changes gradually took place in the Earth's surface and the layers were lifted up to become dry land. Sometimes the layers remained fairly level but often they were turned at an angle or curved. We can call these rocks "layer" rocks. The scientist calls them "sedimentary" rocks. (A sediment is a solid which settles down at the bottom of a liquid, like mud at the bottom of some dirty water.)



Sedimentary rocks. (*Photo: W.E.F.*)

Some sedimentary rocks are made of sand. The sand which we see at the bottom of a stream or on the sea-shore consists of small, yellow particles. In sandstone rocks the particles are firmly stuck together so that the rocks are hard. Some sedimentary rocks are made of clay. One common clay-rock is called shale. Unlike the soft clay which we dig up in the fields, shale is hard and firm. The white cliffs of south-east England are made of chalk. Chalk and limestone (a similar, harder rock) are also sedimentary rocks. They were formed, on the bottom of an ancient sea, from the chalky shells of little sea creatures and from chalk particles which fell to the bottom. Coal is another sedimentary rock. We shall read in Chapter III how it was formed.

Some rocks have been very much changed since they were formed. Rocks, once deep down in the Earth, have been strongly pressed by the weight of rocks above them. Some have been changed by the heat of melted rock which has come near them. Both igneous and sedimentary rocks may be changed by pressure and heat. Slate is a well-known example of a changed rock. It was formed from a clay-rock by great pressure. Some changed rocks have coloured marks and bands and are used for making ornaments.

By studying the kind and age of rocks in any particular district, men can learn where they might find the useful rocks they need. Thus the rocks from which metals are made are often crystalline (made of crystals). They are therefore most likely to be found in places where much of the ground consists of igneous rocks or where igneous rocks have filled cracks in old sedimentary rocks. Coal is a sedimentary rock. It would not be found in a district consisting largely of granite. The sand and mud dropped at the bottom of a river, or where a river has flowed over its banks, may contain small amounts of rocks which the water has picked up in another place. In some countries tin and gold are found in river sand, but usually there is so little useful rock, and it is so much spread out among the sand particles, that men would only waste their time in looking for it.

Some rocks, like chalk and limestone, consist chiefly of one kind of material, but many are mixtures of several kinds. Granite, as we have learned, is a hard mixture of felspar, mica, and quartz. Each pure material found in a rock is called a "mineral." Chalk consists of one

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granite consists of three minerals. We can r and ask "What are minerals made of?" ust leave our main story for a short time and read different kinds of materials. You know the metal We may heat gold, we may pass an electric current ugh it, we may try all kinds of experiments on it, but never succeed in getting any new material out of it. We cannot decompose it, that is, we cannot split it up, into two or more materials different from gold. We say that gold is an "element." We cannot decompose an element. Iron, copper, tin, and all pure metals are elements. Carbon (the black mat al in half-burned wood and in coal) is an element. T air consists chiefly of two gases called oxygen and nitrogen. Each of these gases is an element. The very li t gas hydrogen, which is used in balloons and air-ships, an element. Sulphur, best known in the form of a yello powder, is an element. Altogether there are about 90 ments but only about 20–30 of them are common.

Many other common mate ls are not elements. Thus water is not an element. e can easily decompose it, by means of an electric cur t, into the two gases oxygen and hydrogen. If we s light to a mixture of oxygen and hydrogen they join t ether and make drops of water. So water consists two elements joined together. We call it a "comp und." Salt is a compound. From it we can obtain a metal (sodium) and a gas (chlorine). Sugar is a com ound of three elements —carbon, oxygen, and hydroge

We must be sure we underst d the difference between a mixture and a compound. uppose we mix together some iron "filings" (made by rubbing an iron bar with a file or similar rough tool) d some sulphur. If we look carefully we can still see e shiny bits of iron and the dull, yellow bits of sulphur. If we dip a magnet into the mixture we can pull out the bits of iron and leave the sulphur behind. The two elements are only mixed together. But iron and sulphur can be made to join together to form a compound. All parts of this compound look alike; we cannot see the different bits of iron and sulphur. A magnet will not separate the iron from the sulphur, in fact, we cannot easily separate them. Let us take another example. Iron rust is a compound of iron and oxygen. It does not look like iron and it certainly does not look like the gas oxygen. The two elements are joined together, we cannot easily separate them, and the compound looks quite different from either of them.

As we go along we shall have to use the names of various compounds. Do not be frightened by names. Learning the name of a compound is no harder than learning the name of a friend, and we will explain all names as fully as we can. We will learn one name now. When an element joins with oxygen the compound is called an "oxide." Thus a compound made from iron and oxygen is called iron oxide (or, sometimes, oxide of iron). In the same way, a compound made from tin and oxygen is called tin oxide, and so on.

Many useful minerals are oxides. Thus the rocks from which many metals are made consist chiefly of the oxides of the metals. There is one oxide which is far more common than any other. It is the oxide of an element called silicon. Now you may never see this element (it is a dark brown powder) but you have certainly seen its oxide. Sand consists chiefly of silicon oxide; quartz is almost pure silicon oxide. This oxide is so common that we give it a special, single name. We call it "silica." The many kinds of sandstone, therefore, consist chiefly of silica. There are also more complicated compounds which consist of silica joined with other metals. These compounds are called "silicates." Felspar, mica, and most igneous rocks consists of various silicates. Clay is an impure form of aluminium silicate.

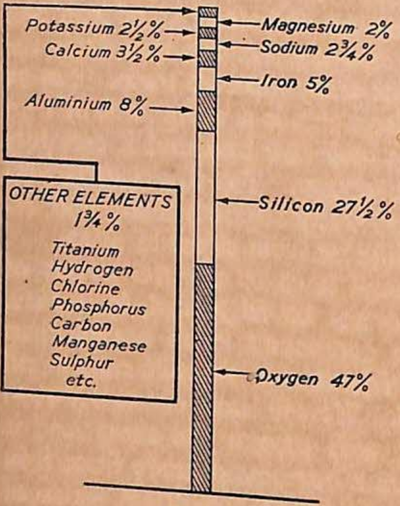

FIG. 1.

In 1924 two American scientists tried to find out how much there is of each element in the outer 10 miles of the Earth's crust. They could not, of course, examine the whole of this very big amount of rock, so they examined samples taken from rocks all over the world. As you might expect, they found that oxygen and silicon are the most common elements. Aluminium is the next most common (clay-rocks are aluminium compounds) and then comes iron. Fig. 1 shows the amounts of the most common elements.[1] Remember that, usually, the elements are joined together into compounds. Chalk and lime contain the metal calcium. Salt and soda are well-known compounds containing the metal sodium; potassium compounds are similar. You have probably heard of most of the other elements named in the drawing (it does not matter if you have not) with the exception of titanium. This metal is not often seen. Its compounds are spread through the rocks in the Earth's crust so that there is very little in any one place. But, you may say, the drawing does not show copper, tin and other well-known metals. No, these elements are less common in the Earth's crust than those shown. Fortunately, the rocks which contain them are not spread all over the Earth but found in heaps in different countries. Then, if men look in the right places, they find enough for their needs.

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[1] The amounts are marked in percentages. 47 per cent. (written 47 %) means 47 parts out of 100.

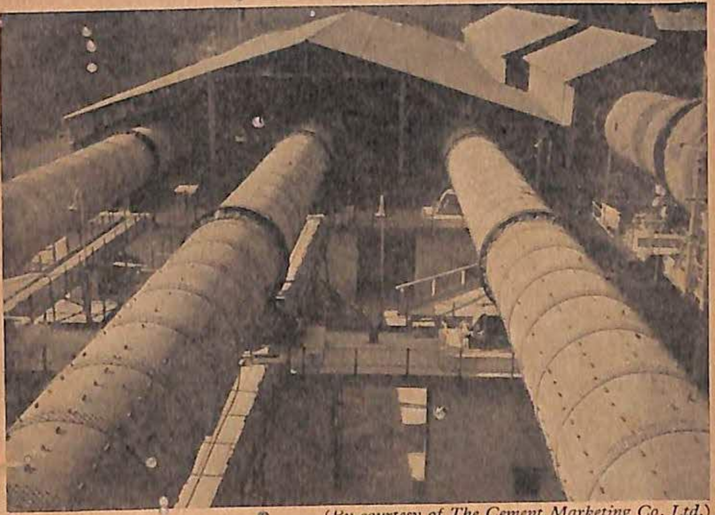
Notice that limestone is not made of lime but is the rock *from which* lime is made. Pieces of limestone are put into a special oven and strongly heated by a coal fire or by hot gases. The picture on p. 13 shows one of the kinds of oven which is used. A strong stream of air carries the carbon dioxide away and the quicklime is left behind.

Quicklime is a hard, white substance. When a little water is poured over a piece of quicklime it becomes hot and gradually turns into a fine, dry powder. This powder, which we call "slaked" lime, is the ordinary lime which you know.

A builder uses "mortar" to join the bricks together. He adds enough water to quicklime to change it into slaked lime and to make it into a paste. Then he adds some sand and, sometimes, some ashes. This mixture is mortar. He puts it, while it is still soft, between the bricks. It gradually becomes hard. First it dries and then the lime in it takes carbon dioxide from the air and slowly changes back into limestone. The builder may add a little cement to the mortar to make it stronger.

Cement is a very important building material. An Englishman found out how to make it, from clay and chalk, about 130 years ago. The clay and chalk are finely ground and mixed in exactly the right amounts. The mixture is then heated until it just begins to melt. The picture on p. 15 shows some of the long, round ovens which are used. When it cools it forms solid pieces. These are then ground into a very fine powder.

For ordinary building purposes the cement is mixed with sand and made into a paste with water. This paste gradually changes into a kind of hard stone. Strangely, it can harden even if it is under water. It is used for many purposes. It is often made into bricks or blocks. These can be used instead of stone or ordinary bricks. Houses are often built from cement blocks.



(By courtesy of The Cement Marketing Co. Ltd.)

Cement kilns (ovens).

If little bits of brick or stone are mixed in with the sand and cement a stronger material is made. We call it "concrete." Scientists have studied how best to make concrete and, if properly made, it is one of the strongest building materials known. It is used for making bridges, roads, and big buildings. Sometimes it is made into blocks and used instead of bricks but more usually walls are made all in one piece. First, wooden boards are fixed up with a space between them. The concrete paste is then poured into the space. The boards are left up until the concrete has become hard. When the boards are taken away a strong concrete wall is left.

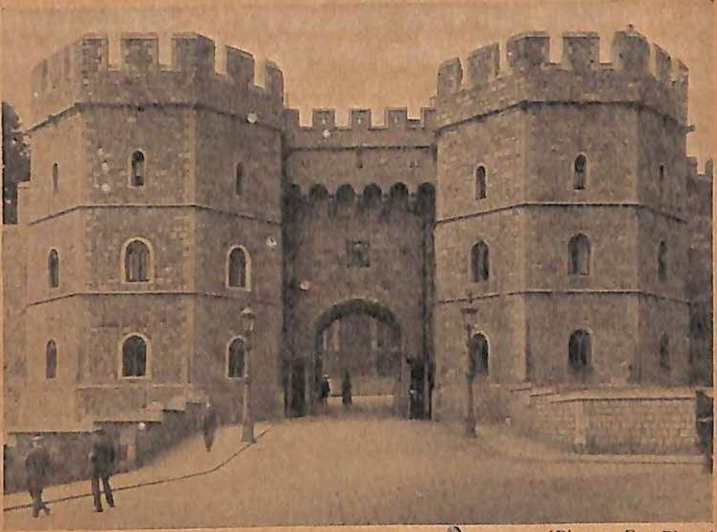
CHAPTER II

BUILDING MATERIALS

WHAT materials were used for building the house in which you live? What materials were used for the big buildings in your town? Throughout the ages, and in different countries, men have used many different kinds of building material. Houses have been built, for example, of stone, brick, baked mud, wood, cement, metal, and even, in very cold lands, from hardened snow. Most building materials come from rocks in the Earth. We will read in this chapter about some of the more important of them.

Big buildings are usually made of stone. The ancient Greeks and Romans built wonderful stone temples and in many countries there are fine stone churches and castles. Almost every kind of rock has been used, at some place, for building-stone. The best kinds of rocks are those which can be shaped fairly easily into blocks of suitable size and yet are strong and lasting. Hard kinds of sandstone and limestone make very good building-stones and they have been used for many famous buildings. Windsor Castle is made of sandstone. Some fine buildings have been made of granite but, as it is a very hard rock and does not split easily, it is not often used.

We do not often use stone for smaller buildings such as houses. It would cost too much to shape the stone and carry it to the place where the house is to be built. Ordinary buildings are usually made of hard clay, bricks, or cement. For most purposes, the builder depends upon three important rocks. These are clay, sand, and lime-



(Photo : Fox Photos)

The entrance to Windsor Castle (England). A fine example of a sandstone building.

stone. From them, all common building materials are made.

Clay is a very common rock. It is soft and sticky when it is wet and you can easily press it into different shapes. When it dries it becomes hard. Pure clay consists of very small particles of a kind of aluminium silicate (p. 8) but usually it also contains small particles of other rocks such as sand, felspar, and chalk. Mud is a kind of clay. Shake up some mud with some water. It settles to the bottom very slowly. This is because the clay particles are very small.

Ordinary dry clay can be made soft again by adding water. If, however, clay is heated strongly, it becomes a hard stone-like mass. It cannot now be softened again

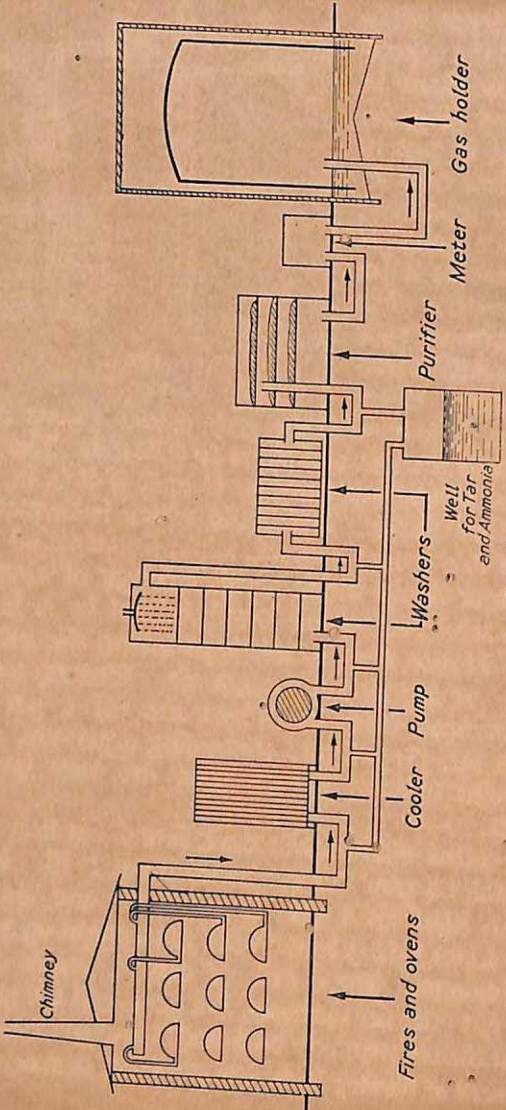
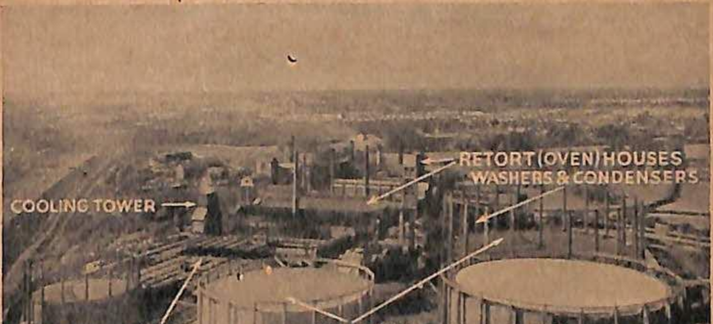

Chimney
Fires and ovens
Cooler
Pump
Washers
Well for Tar and Ammonia
Purifier
Meter
Gas holder

FIG. 4.

as in this chapter for example, it is quite clear what we mean, we just use the name "gas." There are "gas-works" now in most countries where coal is common. The picture below is a view of a gas-works. Let us read what happens there.

Fig. 4 shows the main parts of a gas-works. The coal is heated in large ovens. Some ovens hold as much as 1 ton of coal each, and in a large gas-works there may be as many as 300 ovens. A pipe leads from each oven to a large pipe at the top of the building. The impure gas, which contains drops of tar and water, and looks like green-grey smoke, passes into this large pipe. Next, as in the experiment, the impure gas is cooled. It passes through iron pipes which are cooled by the air which is round them or by running water. Here, most of the tar and water comes out of the gas; they run away into a hole or container called a "well." The gas is now



(*By courtesy of the North Thames Gas Board*)

View of a gas-works (England).

by water. Bricks, cups, pots, and other similar things are made by first shaping wet clay and then baking the clay to make it hard.

We do not know who first found out how to make bricks from clay. The Egyptians made bricks over 4,000 years ago. In very hot countries buildings can be made of mud or clay bricks which have been hardened in the sun, but the best bricks are made by heating the clay in a special oven. The clay is ground to fine powder, mixed with a little water (and, sometimes, a little sand), and pressed to the proper shape. After drying in the air, it is baked in the oven. Ordinary bricks are porous, that is, there are very small holes in them (too small for you to see) and they draw up water just like a rag or piece of blotting paper. If the clay is heated to much higher temperature, parts of it melt and fill up the holes. Then the bricks are not porous.

Millions of bricks are used for building houses. The colour of a brick depends upon the impurities in the clay. Many bricks are red. This is because clay often contains small amounts of iron compounds. In the making of the bricks these compounds form a red rust-like substance.

Different kinds of clay are used for different purposes. Rough pots and jars can be made from impure clay but only special kinds of pure clay can be used for making things like cups and saucers. We shall read later about the big " furnaces " used in the making of iron and other metals. The insides of these furnaces are made of " fire-bricks " which can withstand strong heating without cracking or spoiling. Fire-bricks are made from the clay (called fire-clay) which is found below a layer of coal (see Fig. 2).

Several important building materials are made from lime. We know lime best as the white powder which

(*Photo : Picture Post Library*)

" Lime burning."—Heating the limestone in kilns (ovens) to make quicklime.

we put on the soil to make it better for growing plants. It is made by heating chalk or, more usually, limestone. Both chalk and limestone consist of a compound called calcium carbonate. When calcium carbonate is heated, it decomposes, or breaks up, into a form of lime (called quicklime) and the gas carbon dioxide. We can write the change in this short way:

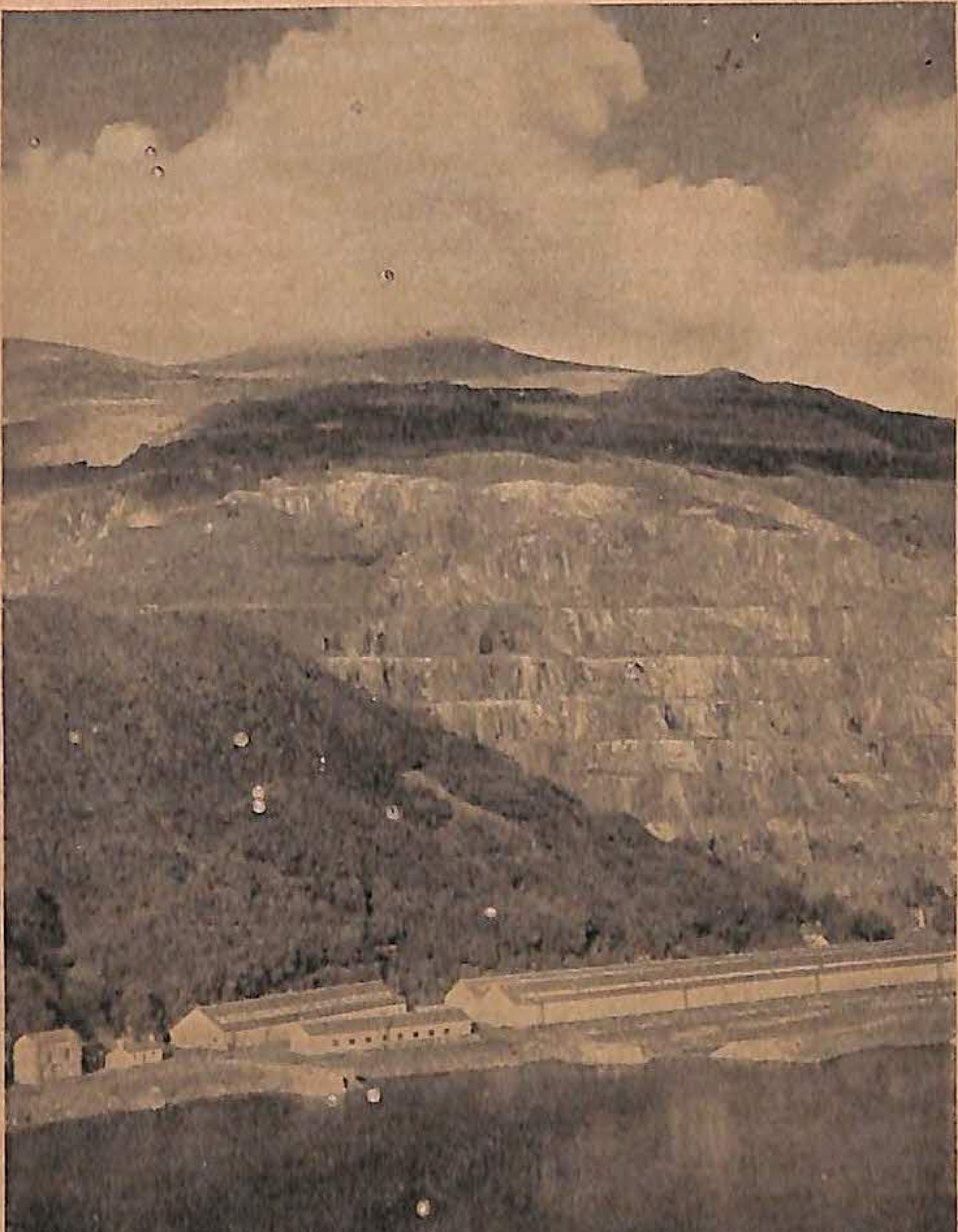
calcium carbonate ⟶ quicklime + carbon dioxide

(We use the sign ⟶ to mean " makes " or " becomes.")

In London and other big cities there are some very big buildings. These are strengthened by steel bars inside the walls. First the framework of the building is

(*Photo by Ewing Galloway, N.Y.*)
Sky-scrapers in New York.

made with the bars and then the walls, of stone, brick, or concrete, are built round them. You have probably heard of the very tall buildings in some cities in America. We call them "sky-scrapers." You can see some in the above picture. Some of these are nearly 1,000 feet high and have 70 or more rooms one above the other. These great buildings actually bend a little in the wind but they are perfectly safe because of the steel bars in their walls.



(*Photo : Val Doone*)

A slate " quarry " where slate is cut from the mountain side (North Wales).

(By courtesy of the North Thames Gas Board)

Retorts (ovens) in a large gas-works.

fairly clear but still contains ammonia and other impurities. The gas is therefore pumped through further containers where it is "washed" and then purified. Two kinds of washers are shown in the drawing. The first is a tower packed with wooden boards or old pieces of coke. The gas passes up the tower and water drips down from the top. The water dissolves the ammonia and carries it away to the well. In the second washer of the drawing, the gas passes between moving pieces of metal which are kept wet with water. In the "purifier" the gas passes over trays of iron oxide. This takes away an impurity called hydrogen sulphide. (The unpleasant smell of a bad egg is due to hydrogen sulphide.) The gas next passes through a meter, which measures how much gas is made, and then into big gas-holders. These are clearly seen in the picture on p. 29. Here the gas is stored until it is needed.

Let us see what we get from ONE TON of coal. Roughly, we get

270 lbs. (or 13,000 cubic feet) of gas
1500 lbs. of coke (left behind in the ovens)
120 lbs. (about 11 gallons) of tar
Enough ammonia to make 25 lbs. of fertilizer (see later).

The rest is chiefly water.

For many years gas lamps were very common in the houses, streets, and factories in England. Now electric lamps are more often used. Gas is much used, however, for heating purposes. Most houses in England have cooking ovens which are heated by burning gas, and some factories use gas in a similar way. The gas is sent from the gas-works to the houses and factories in big pipes buried under the streets. The coke, too, is a fuel. It does not burn so well as coal, and does not make a flame, but, if it is first made hot, it continues to burn. It is used in many houses and factories for boiling water. The coke also has other uses; we shall meet it again later in the book. We see, then, that from the dirty coal, which makes smoke and ash when it burns, we get two other fuels (gas and coke) which are cleaner and more useful.

The ammonia is used to make a substance called sulphate of ammonia. All compounds of ammonia contain nitrogen. A farmer adds sulphate of ammonia to his soil to provide the nitrogen compounds which growing plants need. A substance which is so used for improving the soil is called a "fertilizer." Even the material left

Various kinds of materials have been used for making the roofs of buildings. For hundreds of years men have made very good roofs of sticks and straw but many roofs are made now of "tiles," that is, flat pieces of stone or brick. Slate is much used for making tiles. This is a "changed" rock formed from clay by great pressure inside the Earth. Some of the best slate in the world is dug from mountain-sides in North Wales. The picture on p. 17 shows one of the digging-places. Slate splits very easily into thin, flat pieces. These pieces make excellent tiles.

Asbestos is another material, which, particularly in recent years, has become important in building. In England asbestos tiles are used for huts and small buildings, but in some countries (such as parts of Africa) both tiles and building blocks are far more widely used. The mineral consists chiefly of magnesium silicate. It is a strange mineral for it is made up of fibres (threads). The fibres are separated by crushing and boiling. Long fibres (e.g. over $\frac{1}{4}$ in. long) can be spun and woven into a kind of asbestos cloth. Short fibres are made into a paste with water and pressed into sheets and blocks. For building purposes, a little cement is added.

The most important quality of asbestos is that it does not burn. It is therefore used for making firemen's clothes, brake linings (for cars), and fireproof wall linings. It is also a bad conductor of heat, that is, it does not let heat pass through it easily. It is wrapped round pipes which carry steam in factories to keep in the heat. Asbestos tiles and building blocks have the advantage that they keep out the heat of the sun (hence their use in hot countries) but the tiles break rather easily and may be blown away by the wind.

Most buildings have glass windows. Have you ever thought how useful glass is to us? Make a list of all the glass things which you use in your home. You will be surprised at the length of the list. Glass does not wear, we can clean it easily, it can be made into all kinds of shapes, and, most important of all, we can see through it. Ordinary glass is made by heating a mixture of sand, soda, and lime. The mixture melts and forms a clear, sticky liquid. As it cools, it becomes more and more stiff, and at last becomes a clear, colourless solid. This is glass. While the glass is still a stiff, half-liquid material it can be shaped. Flat glass is made by pressing the material between rollers. Other substances, such as lead oxide, are sometimes used instead of lime in the mixture, so that different kinds of glass (for example, extra hard glass) can be made.

behind in the purifier has a use. A very important substance called sulphuric acid can be made from it.

We have not yet learned what happens to the tar. At one time men thought it was useless; now it is one of the most valuable substances we get from coal. It is a mixture of very useful compounds. Scientists have been able to separate about 200 different compounds from tar, and from them over 2,000 useful substances can be made! Quite clearly, we can only describe a few of them in this little book.

Some of the most important substances which are made from tar are dyes. Man's first dyes were made from the juices of berries, flowers, and certain kinds of wood. The dark blue dye called indigo, made from certain plants, has been known for thousands of years. There were not many different dyes and some were difficult or costly to make. Then, in 1856, an English scientist called William Perkin made a dye from one of the substances in tar. It was a pale purple dye; we call the colour "mauve." To-day this dye is not used much but, for a number of years after its discovery, it was used for printing postage stamps. After Perkin's discovery, other scientists, both in England and in other countries, carefully studied the substances in tar and found out how to make a great number of dyes. Some of the dyes are the same as those which were once obtained from plants (indigo, for example, is now made from tar) but many of the dyes are new. It is interesting to note that the "Khaki" (brown) of the British soldier's clothes and the Royal Air Force "blue" are coal-tar dyes.

Many kinds of useful medicines are made from the substances in coal-tar. There are medicines to cure head-aches (such as "Aspirin"), medicines to ease pain, medicines to heal wounds. Most anæsthetics (which are used to cause deep sleep so that a doctor can cut the body of a sick person) are made from coal-tar. Then, from coal-tar, many scents can be made, and also substances to give pleasant tastes to cakes and sweets. Certain useful oils are obtained from the tar. One of them, called benzene (or benzole), can be mixed with petrol (p. 40) to make a very good fuel for motor-cars and aeroplanes. Another one (called creosote) is used for stopping wood from rotting in wet weather. Nylon (artificial silk used for stockings) is made from coal-tar products.

What, then, do we owe to coal? The answer is heat, power, gas, dyes, medicines and many other important substances. Coal is surely the most useful "treasure" from the Earth. That is why we have called this chapter King Coal.

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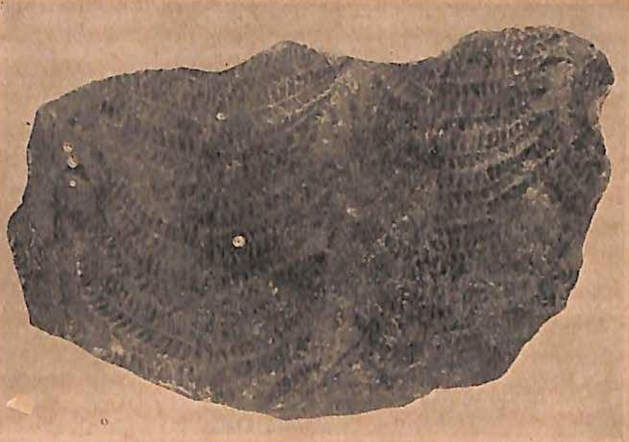
CHAPTER III

KING COAL

GOLD is a very rare substance and is worth a lot of money. Stone and clay enable us to make fine buildings. Iron is certainly a most useful metal. But there is one Treasure from the Earth which is probably more important than any of these. It is coal. That dirty, black rock, which burns so well in a fire, affects our lives in many ways. In England and America coal is well-known, but it is not so well-known in certain other countries such as parts of Africa. This is because coal is not found in these countries (though there are coal mines in Nigeria) and also because, for the purpose of burning, there is plenty of wood in the forests to take its place. Yet, as you will see in this chapter, and in some of the later ones, coal is used in the making of many things which are known all over the world.

What is coal? Suppose you sent a piece of wood and a piece of coal to a scientist and asked him to find out what they are made of. His answer would be much the same for each. He would tell you that both are mixtures of very complicated compounds, and that these compounds consist chiefly of the elements carbon, hydrogen, oxygen, and nitrogen. He would also say that a piece of coal contains more carbon than a piece of wood of the same size. The fact that wood and coal are very much alike does not surprise us when we know what coal really is. Coal is nothing more than the remains of trees and plants which have been buried in the ground for a *very*



Remains of fern leaves in a rock found in a coal mine.

long time and have gradually been changed and pressed into hard, black rock.

Millions of years ago, the seas and the land did not have the shapes which they have to-day. The part of the Earth which we now call England, for example, was, at one time, low-lying wet land covered with a thick forest, with very hot weather much like Nigeria to-day. The trees were different from those which we know now. Many other plants, particularly ferns, grew among the trees. As these trees and plants died, the branches, stems, and leaves fell and made a thick layer on the ground. These remains of plants began to rot. While this was happening the ground was very slowly sinking. Gradually water from the rivers, and perhaps, from the sea, flowed over the rotting remains of the plants. The water brought sand and mud and buried the remains. With the passing of thousands of years the layer became deeply buried in the ground. There, the great pressure and the heat turned the plant-remains into coal. While this was happening, certain gases escaped, so that the coal became richer in carbon than wood.

You may wonder how we know that coal was formed in this way. Fig. 2 shows a hole or "shaft", which is made in the ground to reach the coal. We can see some of the other rocks which are near the coal. The rocks near a layer of coal are always of the same kinds (though sometimes there may be more of one than another). Underneath the coal there is always a layer of clay. It often contains the remains of roots of plants. *It is the soil in which the plants grew long ago.* Above the coal there is always shale (a rock formed from mud or clay) or sandstone or both. These rocks show that the plants were buried in the way which we have described. Then we often find the remains and shapes of plants in the rocks near the coal. (We do not often find them in the coal itself.) They show us what kinds of plants were growing in those times long ago. There are often two, or more, layers of coal (Fig. 2). This shows that plants grew again on the sand and mud which buried the first plant-remains, but they too were later buried.

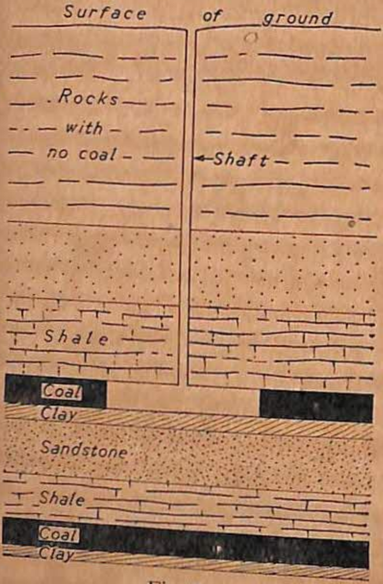


Fig. 2.

There are many different kinds of coal.

Some coal is rather soft and brown-black in colour. It contains 60–75 per cent. of carbon and burns with a very smoky flame. Plant-remains are often found in this kind of coal; it seems to be "young" coal which has not properly formed. Ordinary coal is black and shiny, and it splits fairly easily when it is knocked. It contains 75–90 per cent. of carbon. It burns well with a bright flame, making only a little smoke, and leaving only a small amount of ash. Then there is a harder kind of coal called "anthracite." It contains 90–93 per cent. of carbon. It burns without a flame and makes practically no smoke. It is necessary, however, to heat it strongly before it begins to burn and it must have a good supply of fresh air. It is used in steamships and factories.

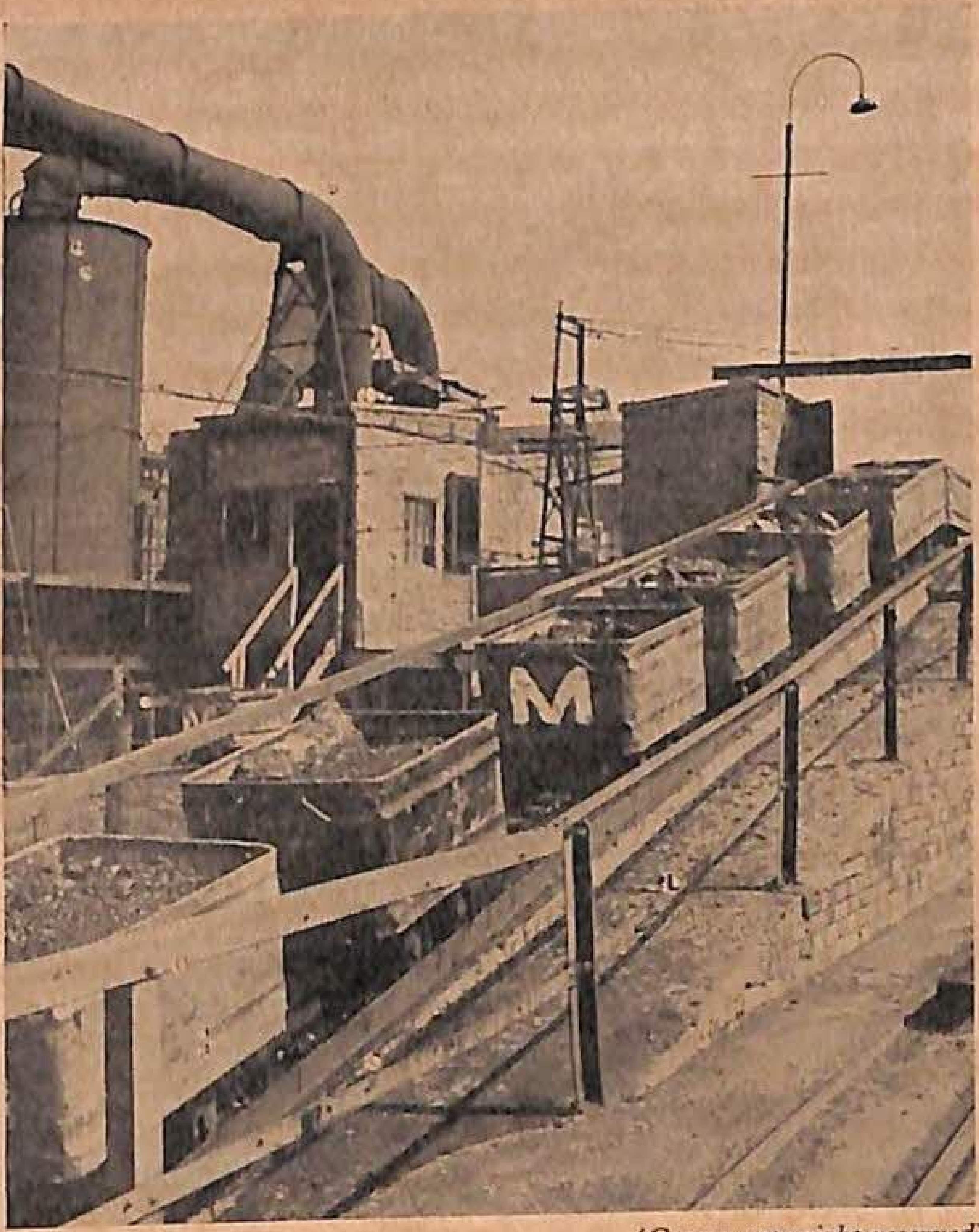
Some coal layers are near the surface of the ground and can be easily reached. In other places the layers may lie far below the surface of the ground. It is necessary then to dig a mine. It may cost thousands of pounds to make a mine, so scientists must first study the ground very carefully to find out if there is likely to be much coal and where the shafts should be made. The sides of a shaft are strengthened by bricks, concrete, or iron. Passages are made sideways from the bottom of a shaft. The "roofs" of these passages are supported by wooden posts. Plenty of fresh air must be supplied to the men who work in the mine. A mine always has two shafts. A kind of fan, worked by machinery, sucks the bad air up one shaft and fresh air passes down the other shaft. It is almost as important to get water out of a mine as to get fresh air into it. Water pumps must work day and night.

The miners are lowered down a shaft in a kind of cage. From the bottom of the shaft the miner has to walk along the passages until, at last, at the end of a dark side-passage, he reaches the coal. He may use his hammer and other

Coal mining (England). Notice the miners' lamps on their caps and the wooden posts for supporting the top of the passage. (Photo : Fox Photos)

tools to break away the coal, or crack the coal by explosives. In big mines, such as some of those in England, coal-cutting machines are used. The coal is carried back to the bottom of a shaft in little trucks like those on a railway. For many years ponies or small horses were used to pull the trucks along but now electric machinery is used. The trucks of coal are then pulled up the shaft in cages.

The coal which comes up from the mine consists of pieces of all sizes, and, very often, pieces of useless rock are mixed with it. The coal is tipped into a kind of tray which has openings in the bottom. The small pieces of coal and of rock fall through the openings and the larger pieces are left behind. Any big pieces of waste rock can be picked out. The small pieces are then "washed." A stream of water is sent through the coal. As coal is less



(Crown copyright reserved)

Coal being carried from the top of a coal mine.

heavy than the rock, the coal is carried away and the stones and rock are left behind. The pure coal is put into railway trucks and taken away to where it is needed.

About half the world's supply of coal is in North America and about a quarter in Russia. There are also large supplies in Britain, many countries of Europe, and China. Every year about 1,500 million tons of coal are taken from the Earth. For what purposes is this great amount of coal used ?

First, we think of coal as a fuel, that is, a material for burning. In cool countries, such as England, it is burned in fires to keep houses and other buildings warm. It is also used in the furnaces in which iron and many other metals are made. Then we think of engines which obtain their power by the burning of coal. In a steam-engine, the burning coal makes the water boil, and the steam pushes the piston.[1] Steam-engines pull the trucks on the railways, drive some of the big ships, and work the machines in many of the big factories. Steam-engines also work the generators for making electric power. It is certain that, wherever you live, some of the things you use (such as clothes, books, tools) were made by machines which, in some way or other, depend upon coal.

Coal, then, is important because it supplies us with heat and power. It is important, however, in another way as well. It is a mixture of very useful substances. Let us see what these substances are, and what use is made of them.

You could try this experiment with a piece of coal. You would need a tin, several inches tall and an inch or so wide, with a well-fitting lid. Make a hole in the lid with a nail. Nearly fill the tin with small pieces of coal, and put on the lid. Place the tin in the fire so that it is heated on all sides. Soon a grey smoke comes out of the hole in the lid. The smoke probably catches alight with the heat of the fire; if it does not you can light it with a match or a piece of burning paper. The smoke burns with a yellow flame. After the flame has gone out, take the tin out of the fire and leave it to cool. Then look inside the tin. You find a grey, easily broken, material.

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[1] The steam-engine is described more fully in *Machines and Engines* in this series.

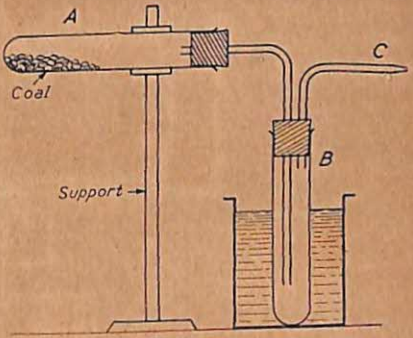

FIG. 3.

In the science room of a school the experiment can be done in a better way (Fig. 3). The coal is put in the wide glass tube A. A narrow tube leads to a wider tube B which stands in a jar of cold water. The second narrow tube C has a small opening at its end. When the coal in A is heated, the grey smoke passes into B. There, part of it cools and turns to a liquid. The rest, a clearer gas, comes out through C and, if it is lit, burns with a yellow flame. The liquid which is formed in B consists of two parts: a black, sticky liquid called "tar," and a clearer liquid which smells strongly of ammonia.[1] The grey substance which is left behind in A is called "coke." Notice that, in this experiment, the coal does not burn. It cannot get enough air. Instead, we make four substances from it. These are (1) a gas which burns, (2) tar, (3) a liquid containing ammonia, and (4) a grey solid (coke). All of these are very important substances.

A boy called William Murdock found out how to heat coal to make a gas. That was in about 1770. He used the gas to light up a cave in which he and his friends played. Later (1801) he used the gas to light up a factory in Birmingham. There are, of course, many different kinds of gas (air, for example, is a gas), and the gas made from coal should properly be called "coal gas," but when,

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[1] The smell of burning feathers is partly due to ammonia.

CHAPTER IV

THE STORY OF OIL

WE can travel over the land in a motor-car, we can cross the sea in a ship, we can fly through the air in an aeroplane. Unlike the railway engine, which obtains its power from coal, the motor-car, the aeroplane, and most big ships obtain their power from oil. Motor-cars and aeroplanes use petrol. This is a thin, easy-running kind of oil. A thicker, heavier kind of oil is burned in the engines of big ships. Oil is clearly a very important material. It has other uses too. As you know, we must put oil on the axles and other moving parts of all machines so that they can turn easily. For example, we "oil" the axles of a bicycle. Then, of course, we sometimes depend upon oil to give us light. Although electric lamps are more often used in the big towns, oil lamps are much used in places where there is no electric supply. Lamp oil is often called kerosene.

Petrol, kerosene, and the other kinds of oil we have mentioned do not come (like palm oil, ground-nut oil, and olive oil) from plants. They come from rocks in the ground. We call them "mineral" oils. There are many kinds of mineral oils but they are alike in one particular way. They are all compounds of carbon and hydrogen. We call them *hydrocarbons*. Some are clear liquids (like petrol), some are thick and sticky, some are solid waxes, and a few are gases. In the last chapter we mentioned benzene. This is a hydrocarbon. Although some hydrocarbons are found in coal-tar, most are obtained from oil in the rocks. Rock-oil, or "petroleum," is a mixture of many kinds of hydrocarbons.

If we read the history of the early Chinese people, we find that they knew that oil could be obtained from the ground in certain places. They sometimes used the oil for their lamps. It was not until about a hundred years ago, however, that men began to make great use of petroleum. They needed better oil for their lamps, and of greater importance, oils to make their machines run more smoothly. The first "oil well" was made, in the United States, in 1859. By 1886 there were many wells and 3,000,000 tons of petroleum were obtained in a year. Then the motor-car and the aeroplane were invented. Now over 250,000,000 tons of petroleum are needed every year. Much of this great amount is produced in America, but oil is also produced in Russia, the Middle East and other countries.

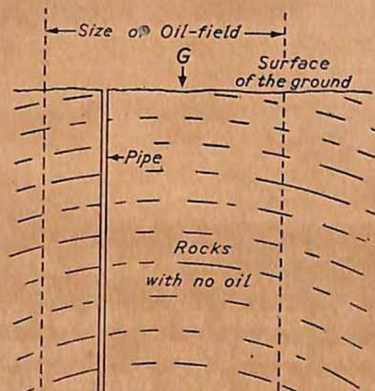
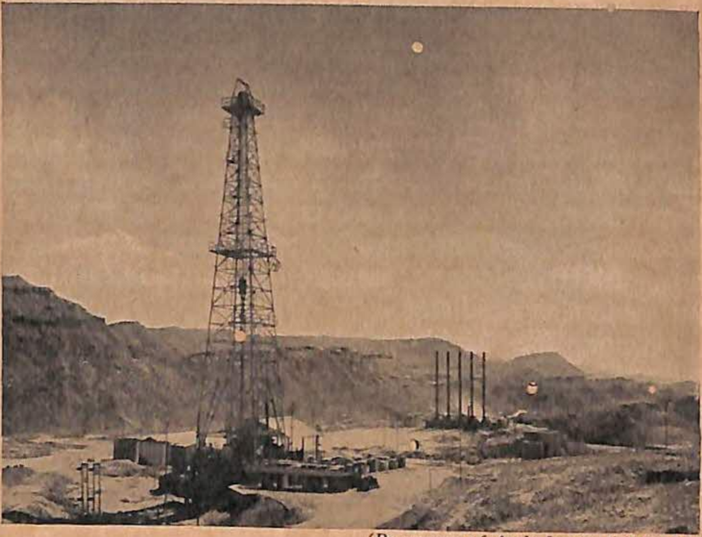


FIG. 5.

Petroleum, we have read, is found in the ground. Fig. 5 shows some rock layers fairly deep down. There is a layer of sandstone below a layer of clay, and the layers are curved upwards. The petroleum fills the very small spaces between the particles of the sandstone. It has risen towards the top of the curve but is trapped there because it cannot soak through the layer of clay. There is usually some gas (something like coal-gas) at the very top of the curve. Scientists are not sure how the oil was formed. Probably, like coal, it was formed by the rotting of plants and animals a very long time ago.



(By courtesy of Anglo-Iranian Oil Co. Ltd. Photo by R. C. Wilson)

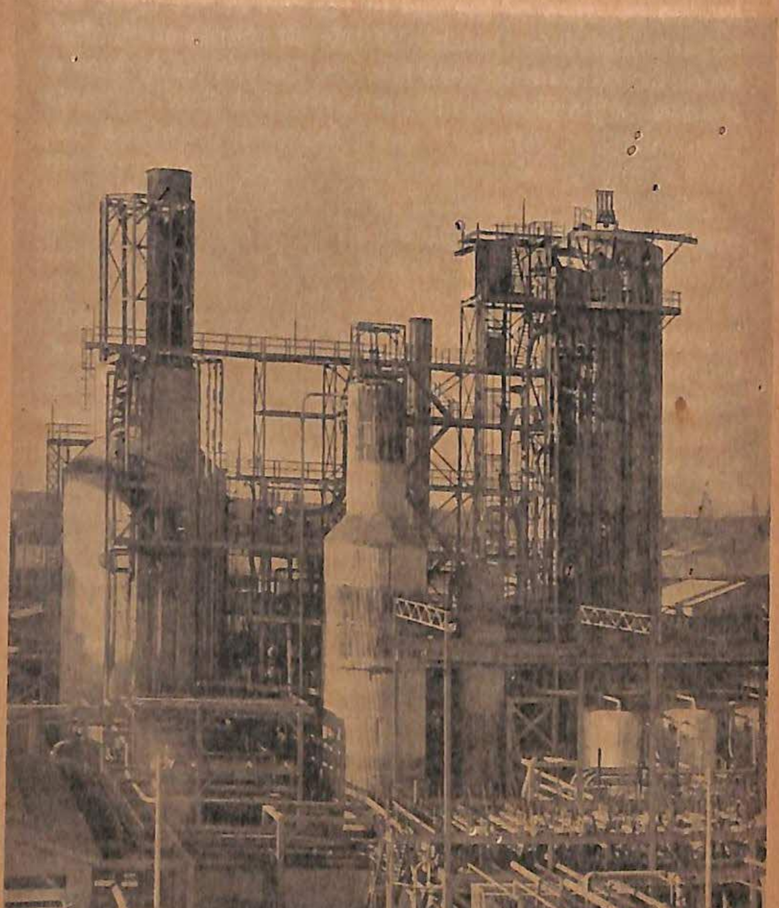
Drilling for oil in Iran (Persia).

We cannot, of course, see the oil which is trapped deep down in the ground. Men must study the rocks carefully. When they think that the rocks in a certain place may contain oil, a metal tower is built. A machine in the tower gradually cuts a narrow hole down into the ground. As the hole is made, a steel pipe is pushed down to stop the sides from falling in and to keep out water. At last, if the men have judged correctly, the hole reaches the oil. Usually the oil rushes up the pipe with great force, driven by the pressure of the gas in the top of the layer, and streams high into the air. If this oil should catch alight there would be a terrible fire. A kind of lid is fixed to the top of the pipe and the oil allowed to flow out gently through taps. After a " well " has been used for a long time it may be necessary to use a pump to get the oil out.

Oil, we see, is obtained more easily than coal. Men must dig coal from a mine but oil rushes up a pipe. Often several wells are made, each reaching the same supply of oil in the ground. They form an " oil-field." We can see from Fig. 5 how the size of an oil-field depends upon the position of the oil in the ground. If a well is made near the middle of the oil-field, as at G, gas will be obtained. This may blow out of the well with great force if it is not controlled. In parts of America such gas is sent through pipes to distant towns, and used, like coal-gas, in houses and factories.

The oil which comes from a well may be a pale brown, easy-flowing liquid, but more usually it is dark brown, thick, and sticky. *It is a mixture of many kinds of hydrocarbons.* The factories in which the various oils (petrol, kerosene, etc.) are got out of this mixture are often many miles away from the wells, in fact, they may be in another country across the sea. The petroleum is sent to these factories, or to ships at a port, through steel pipes. The pipes may cross hundreds of miles of land. Pumps at various places drive the sticky petroleum along. Look at the picture at the front of the book.

When we boil some water in a pot over the fire it changes into a vapour (steam). If we hold a piece of cold glass in the vapour, drops of water form on it. The vapour changes back into a liquid. Now suppose we carefully heat a mixture of petrol and kerosene. (Do not try this ; it might catch alight and cause damage !)



(*By courtesy of Anglo-Iranian Oil Co. Ltd.*)

Factory for separating the various oils in petroleum. The main tower in which the separation takes place is on the right. At this factory 3,000,000 gallons of petroleum are used in a day.

Suppose we make the mixture a little hotter than boiling water. The petrol, which boils easily, turns into a vapour but the kerosene, which does not boil so easily, remains as a liquid. We can collect the petrol vapour and cool it in another container so that it turns back into a liquid. *In this way we have separated the two oils.* There is another, similar way of separating two oils. We can heat the mixture so that both oils turn into vapours and then slowly cool the vapours. The kerosene vapour turns into a liquid first and can be collected ; the petrol does not turn into a liquid until it has been cooled much more.

Petroleum is a mixture of many oils but they can be separated in the ways we have described. The second way is now more common. The petroleum is made very hot and passed into the bottom of a tall tower (Fig. 6). There are shelves in the tower as shown. As the vapours rise up the tower they slowly cool. The thick, heavy oils turn back into liquid near the bottom. Other oils turn back into liquids higher up. The different kinds of oil collect on the shelves. There are taps at the side. The petrol vapour, which is not cooled enough to turn into a liquid, comes out through a pipe at the top of the tower. It is passed through further pipes in which it cools and changes into a liquid. The heavy oil at the bottom of

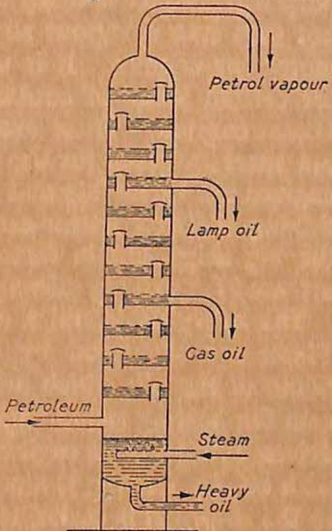


FIG. 6.

the tower is sometimes heated by steam to make sure that lighter oils do not collect there.

Now let us see how much of the different kinds of oil we get. From 100 gallons of petroleum we get, roughly,

30 galls. of petrol (used in motor-cars, aeroplanes)
10 galls. of kerosene (lamp oil)
15 galls. of gas oil (used as a fuel in engines)
45 galls. of heavy oil (which is further separated into other oils and waxes).

The petrol, which must be carefully purified, is used in the engines of motor-cars and aeroplanes. It is a convenient fuel for this purpose because it easily turns into a vapour. Inside the engine it burns *very* quickly (it almost explodes) and provides the power for turning the wheels. Petrol is a dangerous fuel to use for other purposes because it easily catches alight. Kerosene does not turn into a vapour so easily and is not suitable for motor-car engines. It is used mainly for oil-lamps and for certain kinds of cooking ovens. Gas oil is used in Diesel engines. These are similar to motor-car engines but specially made for use with this kind of fuel. Diesel engines are rather big and heavy and cannot be used for driving ordinary motor-cars. They are used in some of the big ships and in factories. In some countries they are used for driving railway engines.

The heavy oil is still a mixture of various compounds. These are separated by further heating and cooling. Some of the oils which are obtained are used instead of coal for heating steam-engines. Very big ships are often driven by oil-heated engines. It is easier to supply a ship with oil, by sending it along pipes, than to carry coal on to the ship. It is easier, too, to store the oil on the ship. We also get, from the heavy oil, all the various kinds of oil for putting on wheels, machine axles, etc. Some of these oils are fairly thin, like the oil you use on your bicycle; some are very thick and sticky. Then we get solid waxes. Candles are usually made of wax got from petroleum. At last we get a thick, black material, something like tar, which is used for making roads and other purposes.

Although so many useful materials are got from the heavy oils, it is the lighter oils which we need most. A very large amount of petrol is needed for all the motor-cars and aeroplanes. Now the heavy oils are rather complicated compounds of hydrogen and carbon, but the lighter oils are simpler. Ways have now been found of "breaking" or changing the heavier compounds into lighter compounds like petrol. (The scientist talks of "cracking" the hydrocarbons.) At first this was done by strongly heating the oil under pressure. Now it is done by adding small amounts of other substances and heating, less strongly, with hydrogen. Sometimes all the petroleum is changed into petrol in this way.

In the last few years men have found out how to make many other useful materials out of petroleum. The hydrocarbons are "cracked" in such a way that many of the substances once got from coal-tar can be made. So petroleum is now almost as important a "treasure" from the Earth as coal.

CHAPTER V

METALS AND THEIR ORES

WE all know the kinds of substances which we call metals. Iron and steel are metals. They are used for making tools, bicycles, railway lines, engines, and many other well-known things. Gold is a bright yellow metal; it is used for making rings and ornaments. Small bullets for guns are made of lead, wires for carrying electricity are made of copper, metal containers are made of iron and tin. Aluminium is a very light metal. It is used for making some kinds of cooking pots and in parts of aeroplanes. Coins are made of silver, copper, and other metals. We use metals in hundreds of ways. Just try to think of all the metal things you have used or seen since you woke up this morning. Your list would be a very long one.

Now in what ways are metals different from other substances such as stone, glass, chalk, and wood? First, most probably, we think of the way in which metals shine. Some metals are white or grey (like silver and steel), gold is yellow, and copper is brown, but all metals, unless they are dirty or rusty, have bright, shiny surfaces. Many other substances do not shine, and those which do (such as glass) do not shine in quite the same way.

Most metals are fairly heavy. Suppose the water in a jar weighs a pound. A piece of stone of the same size as the water would weigh 2–3 lbs. A similar piece of iron would weigh about 8 lbs. and a similar piece of lead over 11 lbs. (In Fig. 7, which shows this very simply, we have left out the weight of the jar.) Gold is heavier still. Of the well-known metals, only aluminium is as light as ordinary kinds of stone.

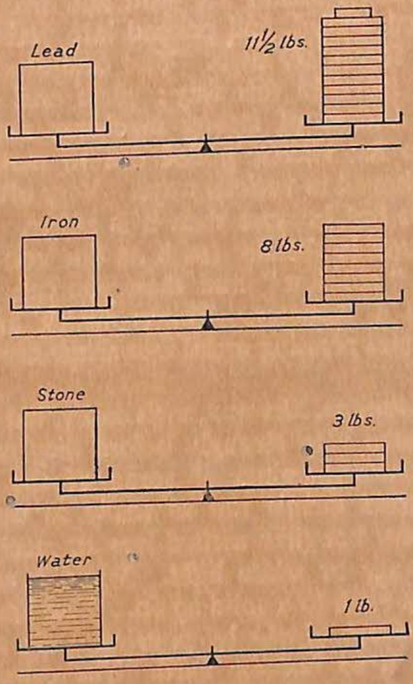


FIG. 7.

Next, of course, we know that most metals are hard and strong. You can easily cut substances like paper and wood, but you cannot cut a piece of steel. You can bend a piece of leather but you can only bend a piece of metal if it is very thin. A piece of clay is soft. You can change its shape by pressing with your fingers. You cannot change the shape of a steel bicycle by pressing it! Metal bars can support heavy weights without breaking.

You can hang a big weight on the end of a piece of wire and the wire does not break.

Although most metals are hard and strong, they can be hammered, pulled, and pressed into various shapes if very strong forces are used. You cannot shape a piece of glass or stone in this way; glass and stone would break. By means of strong machines metals can be pressed into flat sheets, pulled out to make long thin wires, and shaped in various ways. Very often the metal is first made hot because then it is softer. If you heat a piece of iron in the fire (such as the iron of a spade) it becomes "red hot" and then you can shape it by hitting with a hammer. Things which are made by hammering and pressing metal into shape are usually very strong.

Some substances, like wax, melt easily, but most metals must be heated very strongly before they melt. Fig. 8 shows the melting-points of some of the well-known metals. Melted metals run as easily as water. Those which are very hot (like melted iron or steel) shine with a bright orange or white light. When a melted metal cools it turns back to a solid again. You know how you can make cement blocks by pouring cement into boxes and leaving it to become hard. The cement forms a block which is the same shape as the box. In the same way a melted metal can be poured into a "box" made of a substance (such as firm sand) which does not burn. The metal forms a solid which has the shape of the "box." We call the box a "mould" and we call the process "casting." A metal thing which has a complicated shape is usually made by casting but it is not so strong as things made by hammering and pressing.

If two metals are melted, the two liquids can be mixed together (like mixing water and milk). When the mixture

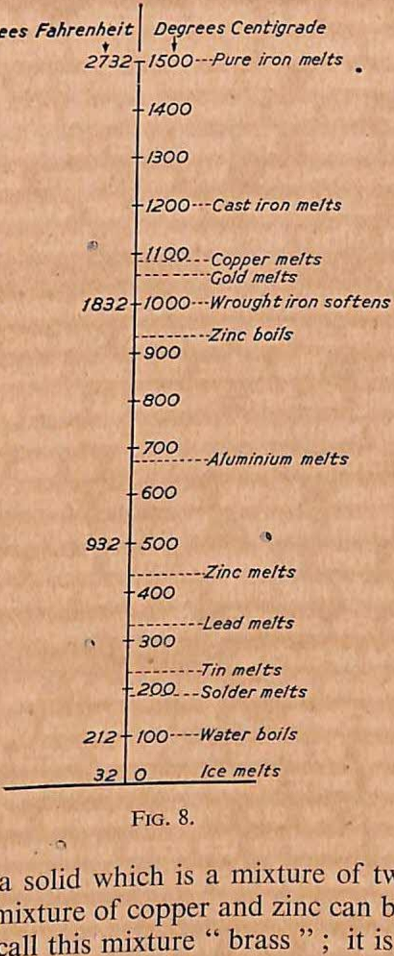


Fig. 8.

cools it makes a solid which is a mixture of two metals. Thus a perfect mixture of copper and zinc can be made in this way. We call this mixture " brass " ; it is the shiny yellow metal which is used for making trays and ornaments. We call a mixture of two metals an "alloy." We can also have an alloy which consists of one or more metals with a small amount of a substance which is not a metal. Steel is a good example. It consists of iron with a small amount of carbon (and often small amounts of other metals). By making alloys we get more kinds of metals. We can choose the best kind for each thing we wish to make. We need hard steel for ships but softer steel for motor-cars. We use copper for electric wires but think that brass is nicer for ornaments. We use aluminium alloys for aeroplanes because they are light and strong.

Metals are different from other substances in still more ways. Leave an iron bar with one end in a fire for a few minutes. The other end also becomes hot. Heat travels along the bar. Metals let heat pass along them. That is why many cooking pots are made of metal. Heat from the fire can pass through to the water (or other things) inside. Metals also let electric currents flow through them easily. We use copper wire to carry electricity from a battery to a lamp and back again. There is only one solid substance which is not a metal but which lets electricity flow through it easily. That is a hard kind of carbon.

From where do we get metals? We get them from rocks in the Earth. A few metals are found " free," that is, they may be *mixed* with other rocks but they are *not joined* with other substances into compounds. Gold is found free; so are small amounts of copper. Most metals are found in the form of compounds. A compound, we know, looks quite different from the elements of which it is made. It is strange to think that from a piece of brown rock we can get a bright, shiny metal. But you know that brown rust is a compound which contains iron although you cannot see the iron. So, too, some of the rocks contain metals, and men have learned how to get the metals from them.

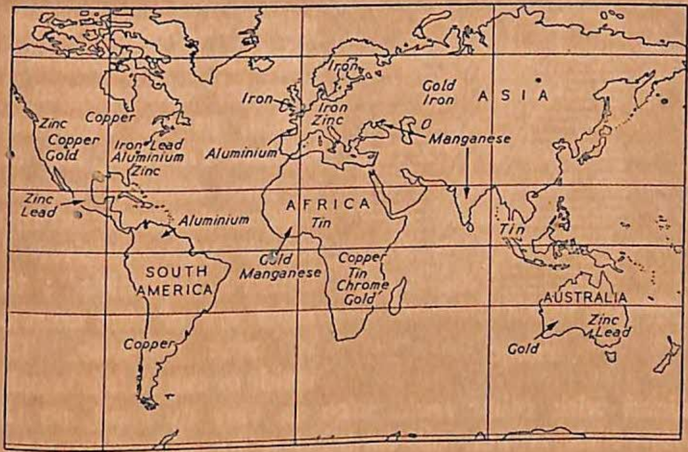


FIG. 9.

A rock from which a metal is obtained is called an "ore." We speak of iron ore, copper ore, and so on. Not all rocks which contain metals are ores. Clay, for example, consists of aluminium compounds but as we cannot easily get the metal out of the clay we do not call it an aluminium ore. Many rocks contain small amounts of iron compounds, but a rock is only useful as an iron ore if it contains a lot of iron. Further, ores are only useful if a lot can be dug up in one place and if that place is one which men can easily reach. Useful ores of at least some metals are found in most countries, but some countries have more ores than others. Fig. 9 is a map which shows where the *most important* supplies of various ores come from. Big supplies of tin ore, for example, come from Nigeria (West Africa) and Malaya (East Asia); much gold comes from South Africa.

The compound in most ores consists of the metal

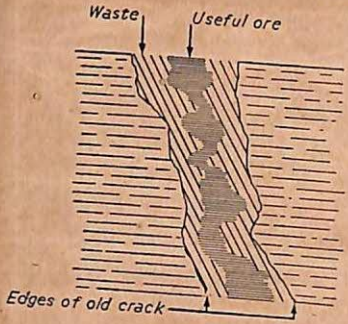
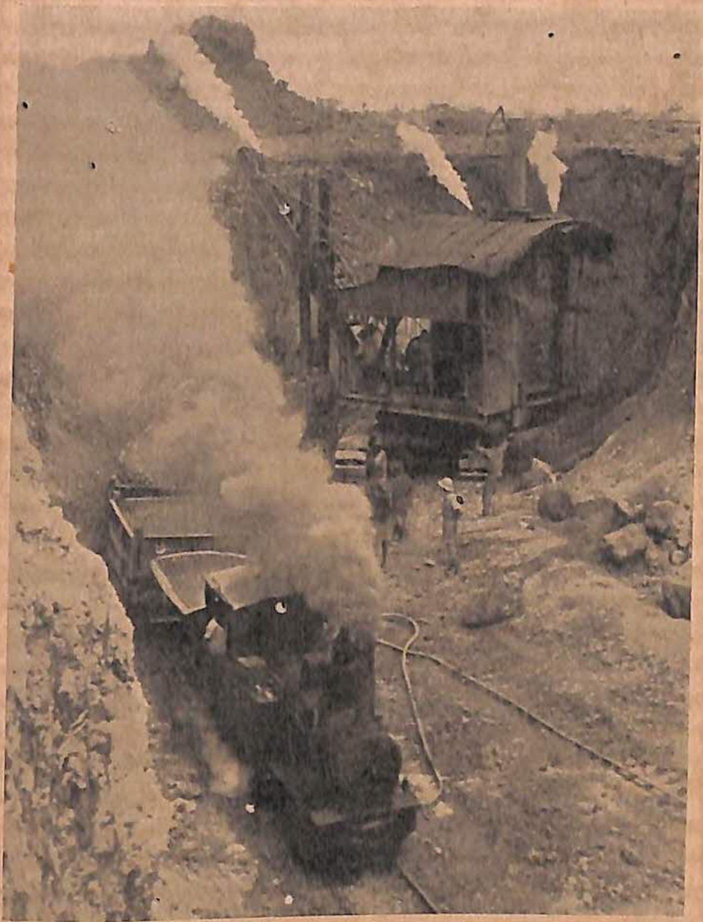


FIG. 10.

joined with oxygen or with sulphur. A compound of a metal with oxygen is called, as we know, an oxide. Tin ore, for example, consists of tin oxide. A compound of a metal with sulphur is called a "sulphide"; the chief ore of zinc consists of zinc sulphide. The oxide or sulphide is usually mixed with other rock, such as clay or sand, so the ore which is dug up contains a lot of useless waste rock. Many metal ores are crystalline. They are found in districts where there are igneous (fire-formed) rocks or where melted igneous rocks have filled cracks in old sedimentary (layer) rocks. Fig. 10 shows an ore in a crack. Melted rock, from deeper in the Earth, has been forced into a crack and crystals have been formed when it cooled. Notice the waste rock (often a kind of quartz) on each side of the metal ore. Sometimes ores have been washed out of the rocks by rain and streams and carried away. They have been dropped into the sand and mud at the bottom of the stream in places where the stream flows more slowly. Much of the tin ore is found in sand at the bottom of streams and rivers (p. 60). Sometimes the ores are carried right away and later form part of newer sedimentary rocks.

Ores which are near the surface of the ground can be dug up fairly easily. The picture on p. 49 shows a machine which is digging up manganese ore. (The metal manganese is described on p. 107.) When the ore is deep



(By courtesy of G. Street & Co. Photo by Robert Gee)

Mining manganese ore near the surface of the ground at Nsuta (Gold Coast).

in the ground a mine, something like a coal mine, must be made. Often the "shafts" are not made to go straight down; the direction depends upon the positions of the ores. Some mines are very deep; some of the gold mines in South Africa, for example, are over 8,000 feet deep—about 1½ miles!

We have read that the rock which is dug up may consist partly of waste material such as sand, stones, and clay. If there is not much waste (as in the case of many iron ores), it is left in the rock, and later got rid of during the actual process of getting out the metal. Some ores, such as those of lead and copper, are mixed with a lot of waste rock. Then as much of the waste as possible must be got rid of before the process of getting the metal begins. The rock is broken and crushed. This breaks the waste rock from the true ore but the two are still mixed together. The mixture is then "washed" in a stream of water. The heavy metal ore sinks to the bottom but the lighter waste rock is carried away by the water. There is also another, newer way of separating the ore from the waste. The crushed rock is stirred up with a special kind of soapy water. The metal ore, rather strangely, sticks to the soap bubbles and the bubbles carry it to the top. The ore can be scraped off from the top of the water and dried.

At last we come to the process of getting the metal from the ore. Many ores, we have read, are oxides or sulphides. The problem is to separate the metal from the oxygen or sulphur to which it is joined. In the case of many metals, this can be done by mixing the ore with carbon (such as coal or coke) and certain other substances and heating the mixture strongly. We call this process "smelting." The smelting of tin and iron ores is fairly simple, but if the ores are sulphides (*e.g.* copper, zinc) the process is more complicated. Some metals, however, cannot be made by smelting. Aluminium, for example, cannot be made in this way; it is made by the use of electricity (p. 92).

Now let us take each of the well-known metals in turn and study how they are made and for what purposes they are used.

CHAPTER VI

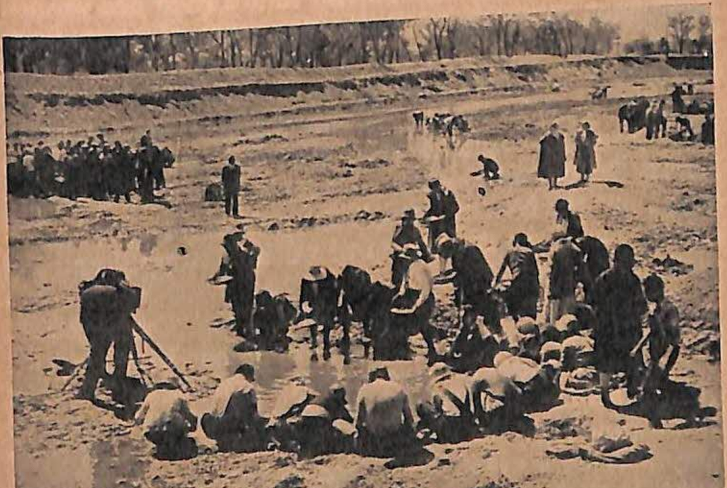
THE ROYAL METAL—GOLD

GOLD is a very beautiful metal. We all know its bright yellow-orange colour. For hundreds, perhaps thousands, of years it has been used for making ornaments. Every woman likes to own a little ornament or a ring made of gold. But, as you know, gold is a very rare metal. A small piece is worth a lot of money. Kings' crowns are made of gold. As gold so often makes us think of Kings and Chiefs we have called it the " royal " metal.

There is one country in West Africa whose name reminds us that gold is found there. That country, of course, is The Gold Coast. People believe that gold was found in the Gold Coast over a thousand years ago. Certainly 400 years ago white men from England and other countries in Europe went to the coasts of West Africa to get gold. They brought goods from their lands and sold them for gold. Although quite a lot of gold is still found in West Africa, much of the world's supply now comes from other countries. Almost half the world's supply comes from South Africa, and gold is also found in Canada, Russia, the United States, and Australia (see the map on p. 47).

Gold is one of the few metals which is found " free." It is not joined with other elements in a compound. It is mixed, however, with much other rock. There are some gold mines in which the miners cannot even see the gold in the rock. As there is so little gold in very much rock, the problem of separating the gold from the rock is a difficult one.

Gold was first found in the sand and mud at the bottom of certain streams and rivers. You have read how streams wear the rocks over which they flow and carry soil, sand, and small stones away. If there is gold in the rock, the water carries away very small particles with the soil and sand. When the stream flows more slowly, perhaps many miles away, the gold is dropped to the bottom with the sand and mud. As gold is a heavy substance, the gold particles sink first, and then sand and mud are dropped on top of them.



(Photo : Keystone Press Agency)

Washing for gold (United States of America).

A small amount of gold is still obtained from the bottom of streams and rivers. The man (or woman) goes to a stream where he thinks gold might be found and fills a pan or dish with some of the sand from the bottom. He carefully washes the sand, picking out the bigger stones, and pouring away the dirty water. He washes again and again, using clean water each time, until he has only fine, clean sand in the bottom of his pan. Then, if he has been lucky, he sees small particles of gold in the sand, shining in the sun. He carefully dries the sand. When it is dry he can blow it away so that the heavier particles of gold are left behind. In this way millions of pounds' worth of gold dust have been obtained in the Gold Coast.

In some countries, particularly Australia, the sand and gravel (coarse sand and stones) near a river are washed in a much bigger way. A strong stream of water, from a pipe, is sent on to the sand and gravel in which it is thought there might be gold. The water breaks the gravel and carries the sand and gold away. It flows down a long wooden channel which has strips of wood nailed across the bottom. The water carries the sand over the strips but the heavier particles of gold are caught by the strips. At times the stream of water is stopped and the gold collected.

Most gold is now obtained from mines. The gold dust in the streams was once part of the rocks in the hills. By following the paths of the streams (in which gold has been found) back to the hills, men have found the valuable rocks which contain the gold. Most of these rocks are very old, and, often, very deep in the ground. Mines must be made to reach the rocks.

The rock usually consists of bits of quartz (a kind of hard, crystalline sand) stuck together by other material. The particles of gold, sometimes too small to be seen, are in this material. The miner makes a hole in the rock with a special tool driven by air under pressure (see the picture). He puts some gunpowder (or other explosive substance) in the hole. Then, from a safe distance, he

(Photo : Fox Photos)

Working in the Robinson Deep Gold Mine (South Africa).

sets fire to the gunpowder. The explosion cracks the rock and breaks off big pieces. The pieces of rock are taken to the bottom of the " shaft " and, like coal, pulled up to the top.

Now begins the process of getting the valuable gold out of the rock. There are two ways of doing this ; we will read about one of these ways. First the rock is broken and crushed by strong machines so that it becomes a powder. The powder is put in a large container. A very weak solution of a substance called sodium cyanide is poured over it. The gold dissolves in the liquid and leaves the rock behind. We have now got the gold out of the rock but it has gone into the liquid. Next the liquid, containing the gold, is made to flow over small pieces of zinc. Some of the zinc takes the place of the gold in the liquid so that the gold is set free. The gold and the unused zinc form a dirty-looking material. The zinc is then burned away, or dissolved by an acid, and at last the gold is obtained. From several *tons* of rock we may get a few *ounces* of gold. The gold is melted and made into solid blocks or bars.

What sort of a metal is gold ? We have mentioned its beautiful colour which air and water cannot spoil ; we know that it can be shaped into ornaments. (We will say more about shaping gold later.) A striking fact about gold is its weight. We have already said that it is heavy. Turn back to Fig. 7, p. 43. Iron is 8 times as heavy as the same volume of water, lead is 11½ times as heavy, but gold is nearly 20 times as heavy ! You know what a cubic foot is. Suppose you had a container 1 ft. long, 1 ft. wide, and 1 ft. tall. It could hold a cubic foot of water. The water would weigh 62½ lbs. You could carry such a container of water. But a block of gold 1 ft. long, 1 ft. wide, and 1 ft. tall would weigh 20 times as much, that is, 20 × 62½ lbs. This, as you can quickly work out, is over half a ton. You certainly could not carry away such a block, without help, however much you might wish to !

Pure gold is a soft metal. It can be shaped easily. An ounce of gold can be made into a wire 50 miles long. Such wire can be wrapped round silk threads and the threads made into gold lace. Gold can be beaten into very thin sheets. We know that 4,000 years ago men in Egypt beat gold into sheets. It is strange that, although machines have been invented to do many kinds of work, no satisfactory machine has been invented for beating gold. A man puts a small piece of gold between two pieces of a special kind of skin and beats it for hours with a hammer. Very thin sheets can be made. Some

(Photo : Keystone Press Agency)

Unloading blocks of gold at the Royal Mint.

are so thin that 200,000 of them, laid one on the top of another, would make a pile only an inch high! If you hold a thin sheet in front of a lamp, weak green light comes *through* it. We use thin sheets of gold to cover things so that they look as if they are made of gold. Temples are sometimes made to look as if they are built of gold by covering the stone and wood with gold sheets.

Rings, ornaments, and coins are not made of pure gold. They would bend and become scratched too easily. Gold for such things is mixed with other metals to make it harder, that is, we make a gold alloy. Gold is often mixed with copper or silver, or, sometimes, nickel. Copper makes the gold rather darker in colour, and silver makes it lighter in colour, so if it is important that the alloy shall have the colour of pure gold both copper and silver, in the right amounts, are used. We use the word " carat " when we wish to describe how much gold there is in an alloy. 24 carat gold is pure. 22 carat gold contains 22 parts of gold mixed with 2 parts of other metals ; 18 carat gold contains 18 parts of gold mixed with 6 parts of other metals, and so on. Rings and ornaments are often made of 18 carat gold. Alloys which contain less gold (for example 14 carat, or 9 carat) are used for things of less value. Pen nibs are often made of such an alloy.

Gold is not a very *useful* metal. It is used chiefly as a store of money. Gold coins are not used now in many countries but all countries like to keep stores of gold in their banks. Then, if one country buys goods from another country, payment could be made in gold. (More often other goods are given in exchange.) At present, most of the gold of the world belongs to a few rich countries. They keep the gold in the form of bars—and they keep the bars in very safe places !

CHAPTER VII

TIN AND ITS USES

YOU all know the metal containers which we call "tins." Some of the food which we buy (such as milk, biscuits, meat, fish) has been preserved in tins. We keep petrol and lamp-oil in tins. All over the world tins are used for many purposes, and often, when they are empty, used again for other purposes. Old kerosene (lamp-oil) tins are useful in many ways !

Although we call these containers "tins," they are not made of the pure metal called "tin." Pure tin is not a strong metal and is costly. The containers are made from thin sheets of steel with a very thin layer of tin on the surface. The steel gives the strength which is needed ; the tin protects the steel and stops it from rusting. If you throw away a tin container, it rusts after a time. The water gets through cracks in the layer of tin and the steel begins to rust. The rust pushes the tin layer away, more water can get in, and the steel rusts more. The making of "tin-plate" (steel plate with a tin layer) is an important industry. Later we will read how it is done.

The making of metal containers was not the first use of tin. Tin ore was found in the south-west of England hundreds of years ago and traders from other countries came to England to get it. Strangely, in this part of England both tin ore and copper ore were found. Long ago men discovered that, by using the two ores together, they could make a very useful alloy. We call this alloy "bronze." It is harder than either tin or copper separately and was therefore useful for making tools, spears, and other weapons. Until men found out how to make iron from iron ore, bronze was the most important metal they had.

Only a little tin ore is dug up in England now. Most of the world's supply of tin comes from countries and islands of East Asia (especially Malaya), from Nigeria, Bolivia, and Belgian Congo. Tin ore is one of the most important of the minerals found in Nigeria.

Tin ore really comes from old fire-formed rocks. As with gold, rain and streams have carried some of the ore away and dropped it, with soil and sand, in other places. So although a little tin ore is dug out of mines in hills, most is obtained from sand which has been dropped by streams and rivers. Sometimes the sand (with the ore) is at the bottom of a river, but more often the sand, once dropped by a river, has been covered with lighter soil. In this last case, the soil is first dug away and then the heavy sand and ore dug out or washed out with water. The tin ore can be separated from the sand by washing (as we described for gold) but harder rocks containing tin ore must first be crushed by machines. Sometimes the tin ore must afterwards be heated strongly to burn away impurities.

Now what exactly is tin ore? It is a compound of tin and oxygen; it is tin oxide. We have the problem, which we mentioned on p. 50, of getting the metal out of the compound. One way of getting a metal out of its oxide is by heating the oxide with carbon. (Coal, we know, consists chiefly of carbon.) Carbon joins very strongly with oxygen. It does this, for example, when coal burns in a fire. If we heat a metal oxide with carbon, the carbon may join with the oxygen and so take it away.

(By courtesy of The Malayan Information Agency)
Washing for tin.

Then the metal is set free. This happens if we heat tin oxide with carbon. We can write the process so:

tin oxide + carbon ⟶ tin + oxides of carbon[1]

As the oxides of carbon are gases, they escape and leave the tin.

The tin ore is mixed with a hard kind of coal. The mixture is heated in a furnace. A furnace is a big fire enclosed in a brick or metal container. We shall

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[1] Carbon can join with oxygen in two ways to make two kinds of oxides. One oxide contains twice as much oxygen as the other. We do not need to distinguish the two kinds of oxides here.

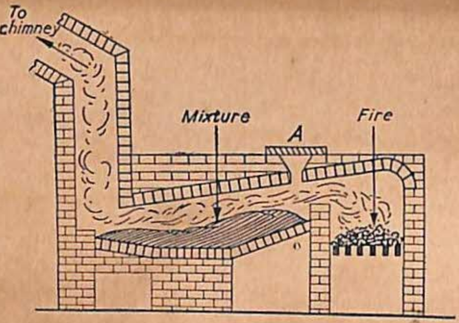
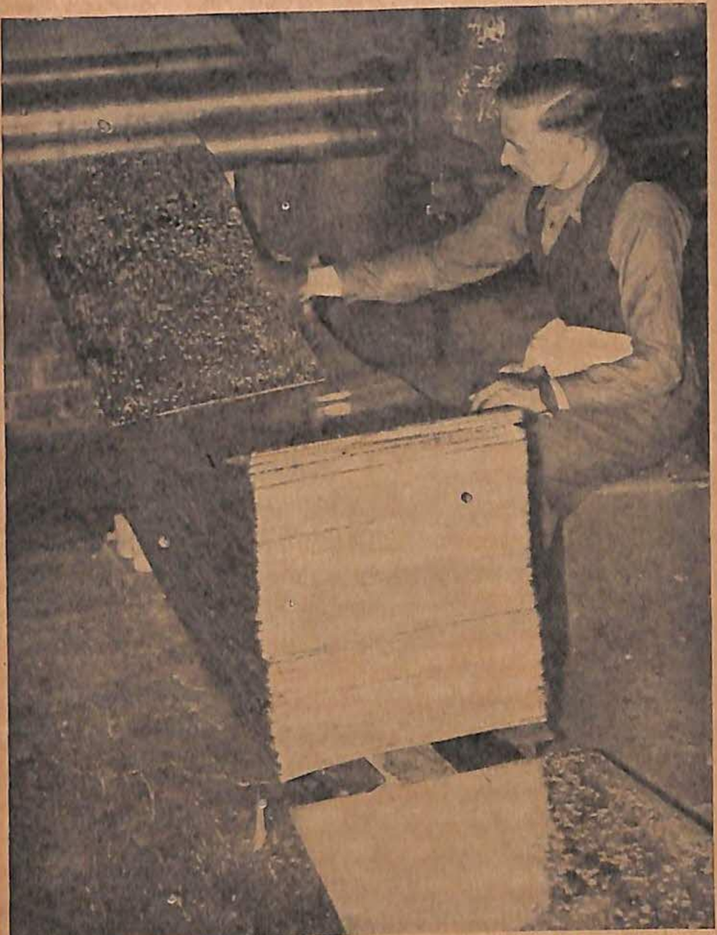


FIG. 11.

describe several kinds of furnaces in this book. Fig. 11 shows a furnace which is suitable for the making of tin. The fire is at one end. The mixture is put in through the opening A. The flames and hot gases pass over the mixture of coal and ore; the mixture is heated chiefly by the heat which is thrown down by the sloping roof of the furnace. The waste gases (oxides of carbon) and smoke go out through the chimney. This kind of furnace is used when it is necessary not to let the coal (or other material) of the fire mix with the things which are being heated. The tin, which is set free, melts and sinks to the bottom of the furnace. From time to time a tap (not shown in Fig. 11) is opened so that the melted tin runs out. The tin cools and forms solid blocks.

Tin is a silvery-white metal, which, unlike some metals, keeps bright and shiny in the air. It melts more easily than other well-known metals (see Fig. 8, p. 45) and is not very hard. About half the tin which is produced in the world is used in the making of "tin-plate."

Much tin-plate is made in South Wales. The steel which is brought to the factory consists of bars about ½–1 inch thick. The bars are made red-hot so as to soften



(*Photo : Fox Photos*)

Tin-plate. The sheets are coming out from the machine in which the layer of tin is put on.

them and then pressed by machines so that, at last, they become steel sheets about $\frac{1}{100}$ inch thick. The large sheets are cut into smaller sheets of convenient size and cleaned with an acid. Then they are dipped into a container of melted tin. The tin forms a very thin layer or film on the surface of the steel. The layer may be only one ten-thousandth of an inch thick. The sheet is pressed to make the layer smooth and even, and then polished with sheep-skin. Some tin-plate is now made by electricity and this method may, in time, take the place of the method which we have described. Over 1,000,000 tons of steel and 16,000 tons of tin are made into tin-plate every year in Great Britain. The tin-plate is used for making all kinds of " tins " and containers.

Tin is also used in the making of several important alloys. We have already mentioned the alloy bronze which is made from tin and copper. Church bells are usually made of bronze, and so also are " copper " coins. (They contain tin as well as copper.) Other alloys which contain tin are used for making spoons and forks. Then there are the " bearing " alloys. Think of the wheels and axles of a railway engine. The ends of the axles fit into metal parts. The axles must be able to turn easily and yet support the weight of the engine. A metal part in which an axle turns and yet supports a weight is called a " bearing." You can speak of the bearings of the wheels of a bicycle. Many of the best kinds of metals for bearings are tin alloys. The bearings of railway engines, for example, consist of tin with small amounts of copper and antimony (an uncommon metal).

Alloys made of tin and lead are very useful. Tin melts at 232° C. and lead at 327° C. but a mixture of the two melts at a lower temperature than either metal ! If the mixture contains twice as much tin as lead, for example, the melting temperature is about 182° C. "Solder," which is used for joining metals, is an alloy of tin and lead. Perhaps you have seen a man mending a hole in a metal container. He carefully cleans the metal near the hole. He heats the end of a copper bar (on a wooden handle) in a fire. Then he takes a stick of silvery-white solder, holds it near the hole, and touches it with the end of the hot bar. The solder easily melts. He spreads the melted metal in and near the hole, using the hot bar, and then leaves the metal to cool. It becomes hard and solid, and closes the hole. There are different kinds of solder according to the amounts of tin and lead which they contain; each kind has its special use. Solder is a very useful material. It is used for joining wires in electric machines and radio sets, for mending holes and cracks in lead pipes, for joining the lead sheets which are used for roofs, for joining parts of motor-cars and aeroplanes. When a piece of tin-plate is bent to make a container, the edges are joined together by solder; when the food has been put inside, the lid is closed with solder.

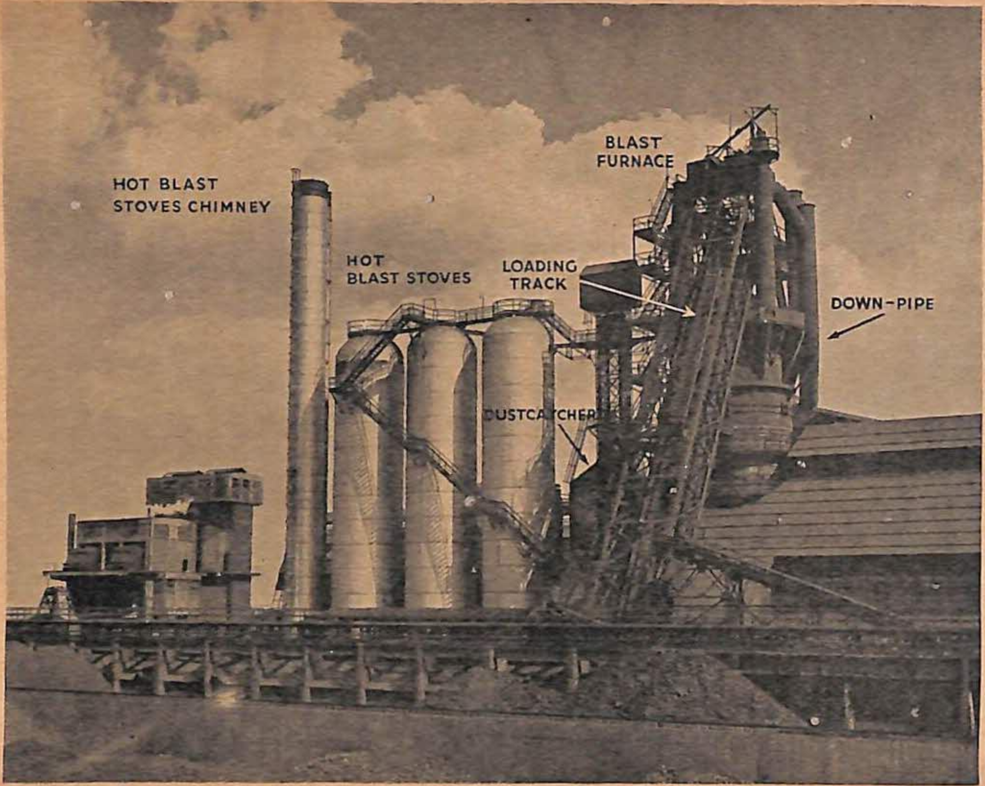
Tin is a strange metal We never see things which are made of pure tin and yet many well-known things could not be made without it. It is an important metal for it is used in so many ways.

CHAPTER VIII

THE MAKING OF IRON

IRON is the most important metal in the world. Many useful things are made of iron or of iron alloys. Steel, of course, is an iron alloy. Let us amuse ourselves by imagining what would happen if, in some magic way, everything made of iron and steel disappeared. Of our bicycles only the tyres and a few bits of leather would be left. Motor-cars would also mostly disappear. There would be no railway lines, engines, and trains; roads would become useless in places where steel bridges had gone; thousands of people would drown when steel ships disappeared from under them. In the house, doors tables and chairs, without nails, screws, and hinges, would become useless pieces of wood. Iron cooking pots would disappear, and great amounts of food, water, and oil, once in "tins," would be lost. Tools would disappear; we should not even have knives for cutting our food. The great factories, without machines, would stop working. You can add more examples to this list. Without iron and steel our way of living would be very different. In this book the stories of the metals take about 67 pages. If we gave each metal the number of pages according to its importance, we should have to give about 61 pages to iron and steel and describe all the other metals in the 6 pages which are left.

Iron is a very common element in the rocks (p. 8). Next to aluminium it is the most common metal. The yellow, brown, or red colour of many rocks is caused by *small* amounts of iron compounds. (Iron rust, you know,



(*By courtesy of the Ford Motor Co. Ltd.*)

A blast furnace.

is red-brown in colour.) But iron ores are rocks which consist *chiefly* of iron compounds. Much iron ore is found in the United States of America, Russia, France, Sweden, and England.

Most iron ores consist of various kinds of iron oxide mixed with other rock. Some ores are "rich" and contain about 65 per cent. of iron, but poor ores may contain only 30 per cent. of iron. Again we have the problem of getting a metal from its oxide. We heat the oxide with carbon (such as charcoal or coke). The carbon joins with the oxygen, forming oxides of carbon, and sets the iron free. We can show the process so :

$$\underset{\text{(ore)}}{\text{oxide of iron}} + \underset{\text{(coke)}}{\text{carbon}} \longrightarrow \underset{\text{(metal)}}{\text{iron}} + \underset{\text{(gases)}}{\text{oxides of carbon.}}$$

This is the important process on which iron smelting depends.

The process has been known for a very long time. Hundreds of years ago men heated iron ore in a charcoal fire. After the fire had died down, a piece of iron was left in the ashes. The iron could be beaten into shapes and made into useful tools. At some time it was noticed that a strong wind made the fire burn faster and hotter, so that the iron was made more quickly. This discovery was put to good use. Men built furnaces, several feet high, of baked clay, and put the charcoal and iron ore inside. Then, after the fire had been lit, they blew a strong stream of air through the fire. The ruins of old iron furnaces can be seen in parts of South England and West Africa, and iron is still made in some districts in this way.

The picture on p. 67 shows a big iron smelting factory in England. Although its buildings and machines seem very complicated, the whole working depends upon the simple ideas which we have described. The great furnace is towards the right of the picture. In other buildings coke is made from coal, the coke is mixed with the iron ore, the air which will be pumped through the fires is dried and heated, and so on. Let us study the details of each part of the factory in turn.

Four important materials are used in an iron smelting factory. These are iron ore, coal, limestone, and air. We have not yet described the purpose of the limestone (we will do so later) but we already know the purposes of the other three. The factory must be built in a place where these materials, particularly the ore and coal, are easily obtained. Sometimes the factories are near both coal mines and iron mines, sometimes they are built in places where there are coal mines near the coast. Then the iron ore can be brought in ships and the coal taken from the mines. The coal is usually changed into coke (p. 27) because coke burns better in the furnaces. Sometimes, but not always, the iron ore is heated in ovens to dry it and to burn away certain impurities. Then the coke, ore, and limestone are mixed together in the right amounts. About 2 tons of an average kind of ore, 1 ton of coke, and ½ ton of limestone are used in the making of 1 ton of iron. (And while it is being made 4 tons of air are blown through the furnace !) The mixture is carried to the top of a furnace on a loading " track " ; you can see it in the picture.

Now we come to the furnace itself. We call a strong stream of air a " blast " and so we call a furnace through which a strong stream of air is blown a " blast furnace." Fig. 12 is a drawing of a blast furnace. A furnace is about 100 feet high and 20–28 feet across at its widest part. The sides, which are 3–5 feet thick, are made of fire-bricks (p. 12) with steel plates on the outside. Nearly a million fire-bricks are used in building a blast furnace. There are two "doors" at the top. These are marked X and Y. They open by moving downwards. Near the bottom there is a wide pipe and from it a number of smaller pipes lead into the furnace. The blast of air is sent through these pipes. At the bottom of the furnace, below the pipes, there are two holes P and Q. These are usually closed by blocks of baked clay but they can be opened when necessary.

The furnace is used night and day. After the fire has been lit, it is kept burning by adding more coke, ore, and limestone, and may not go out for two or three years! After that time the furnace must be cleaned and the fire-bricks mended. The coke, iron ore, and limestone, carried up on the track, go in at the top. First door X opens and the mixture goes through. Then this door is shut and door Y opened so that the mixture goes into the furnace. By using two doors in this way the hot gases inside the furnace cannot escape. The air blast makes the coke burn strongly.

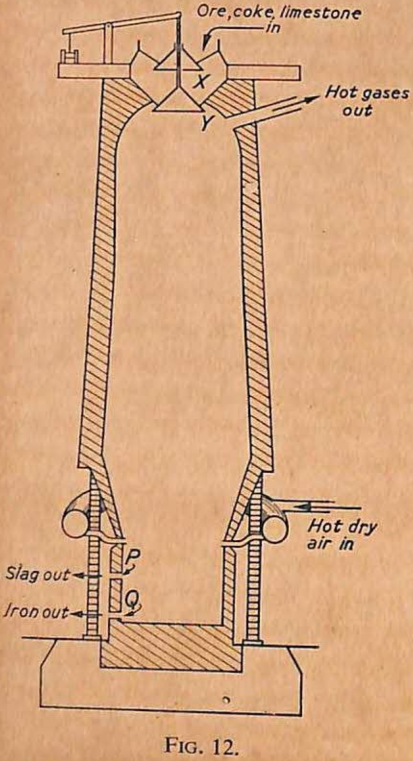
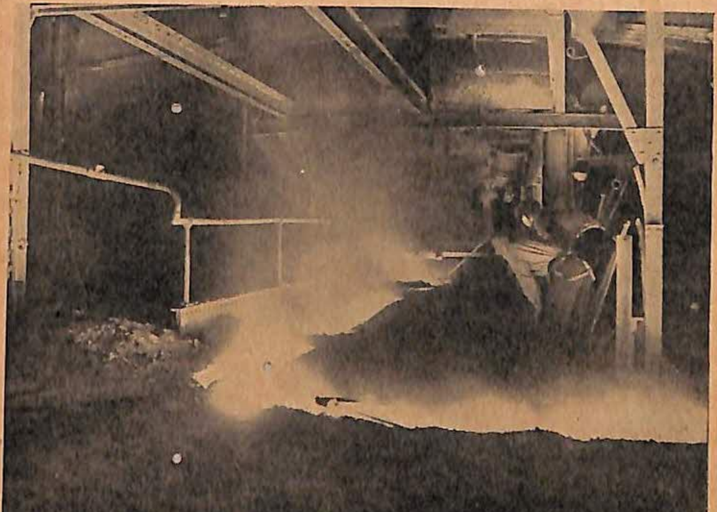


FIG. 12.

As the mixture gradually sinks towards the bottom of the furnace, it becomes hotter and hotter. The iron is set free from the ore, but the temperature near the bottom of the furnace is so high that the iron melts. The melted iron runs to the bottom of the furnace.

Iron ore, as dug from the ground, consists of iron oxide mixed with other, useless rock. You may have noticed that so far we have said nothing about getting rid of this useless rock. Usually it is not separated from the iron oxide ; the ore is put into the furnace with coke and limestone. Now we can learn the purpose of the limestone. In the furnace it joins with the useless rock and makes a stone-like substance *which melts*. We call this substance "slag." The melted slag also runs to the



(Photo : Sport and General Press Agency)

At the bottom of a blast furnace. The melted iron is running out into channels lined with sand.

bottom of the furnace, but, as it is lighter than iron, it floats on the top of the melted iron, just as oil floats on water.

Four or five times a day the holes P and Q (see Fig. 12) are opened. The melted iron runs out of the lower hole Q. You would like to see the iron which runs out from the furnace. It is white-hot. It looks like a bright, shining fire which can run as easily as water. If there is a steel works nearby, the iron is taken there while it is still a liquid. If the iron is not to be made immediately into steel, it runs away in a channel made in a layer of sand. This channel divides into smaller channels and leads to "moulds" (p. 44). The melted iron fills the moulds and, when it cools, forms solid bars. Later the bars are broken into pieces of convenient sizes.

The melted slag runs out of the upper hole P. When it cools it forms a stone-like material. Some of it is used for making roads and special kinds of bricks but much of it must be thrown away as useless.

We have not yet described all the buildings in an iron smelting factory. The picture shows a big pipe leading down from the top of the furnace and, on the left, some

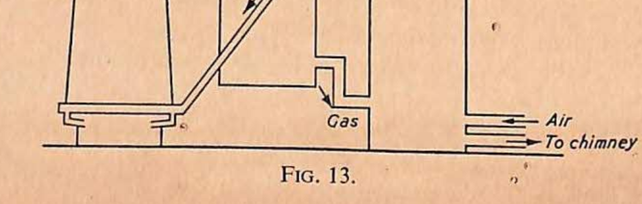


FIG. 13.

round buildings marked "hot blast stoves," and a chimney. In early kinds of blast furnaces, *cold* air was blown in at the bottom. We remember that, in the making of iron from its oxide, oxides of carbon are made. One of these oxides burns well. In the early furnaces the gases, containing this oxide, were allowed to burn at the top. Now men have a better idea. *They use the gases from the top of the furnace to heat the air which is blown in at the bottom.* Fig. 13 is a simple drawing of the arrangement. The gases pass through a pipe at the top of the furnace. After the dust has been taken out, they burn in special stoves and make the bricks inside them red-hot. The air is pumped through a stove which has been made hot and so becomes hot before it goes into the blast furnace. The hot air does not cool the fire when it goes in. So the gases from the furnace are put to a good use.

Let us now go back to the iron which has been made in the blast furnace. We have described how the melted iron runs into moulds and, when it cools, forms solid bars. This iron is not very pure. Inside the very hot furnace the iron was a liquid. Now, just as salt and sugar dissolve in water, so, too, substances dissolve in the liquid iron. The chief of these substances are carbon (from the coke) and silicon (from the silica in the waste rock). So the iron bars contain small amounts of various substances. A bar which weighs 100 lbs. may consist of 92–96 lbs. of iron, 3–4 lbs. of carbon, $\frac{1}{2}$ lb. of silicon, and small amounts of other substances. These impurities affect the iron in an important way. If the iron is hit with a hammer, or dropped heavily on the ground, it breaks. We say that the iron is "brittle." (Glass is a good example of another brittle substance.) If we heat the iron it melts rather more easily than pure iron (see

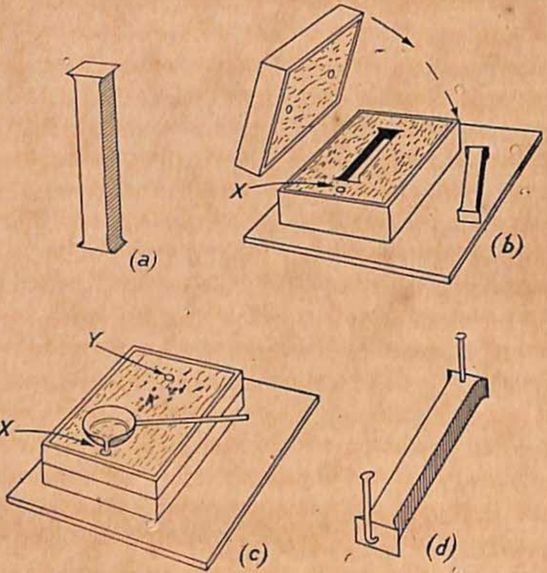
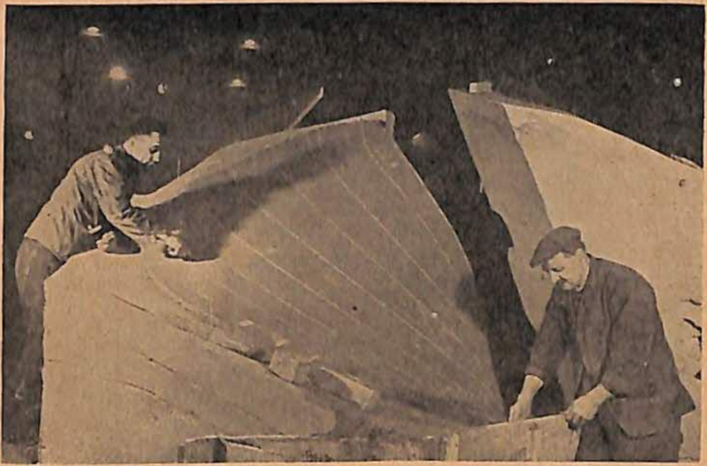


FIG. 14.

Fig. 8, p. 45) but it does not become soft before it melts. *We cannot, therefore, make the iron into useful shapes by pressing and hammering.* We can only shape it by melting it and pouring it into moulds, that is, by "casting." So we call this impure kind of iron "cast-iron."

Suppose we wish to cast an object in the shape of the letter I (Fig. 14a). First we must make a mould of the right shape. A model of the I is made with wood. The model is buried in a box of sand (made firm with a little clay) and the sand packed round it. Then the model is carefully lifted out; it leaves a hole of the right shape. Melted iron could be poured into this hole and, after it became solid, it would form an iron I. But the top surface of the I, as it lies in the box, would not be very



Making the moulds for the propellers of the "Queen Mary."

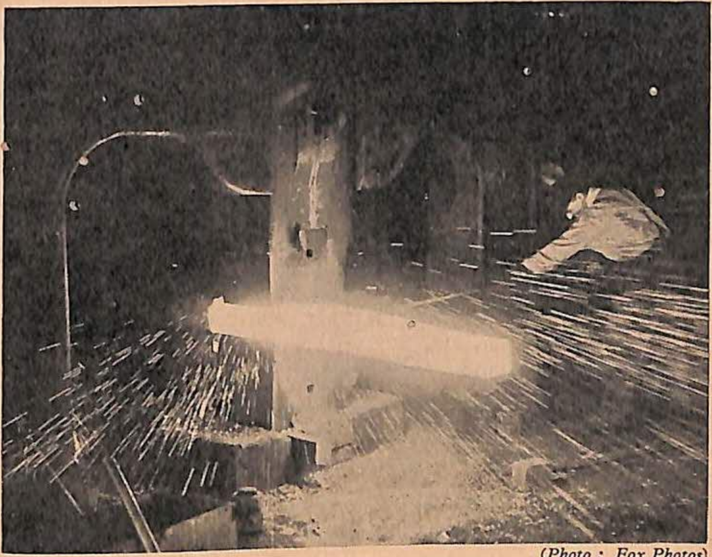
(Photos by courtesy of J. Stone & Co. Ltd.)

Getting ready to cast the propellers in the moulds. Notice the large buckets of melted metal.

flat. So, more usually, another box of sand is put on the top (Fig. 14b). For a simple object like our letter I the sand in this box would be flat. The " hole " (shaped like the I) is now right in the middle of the sand. A little hole X must be made through the sand so that the metal can be poured in and another hole Y so that the shape can be properly filled. For small things, the metal is poured in from a kind of spoon (Fig. 14c). After the metal has cooled and become solid, the two boxes are separated and the sand taken away. Inside is a solid metal I (Fig. 14d). It has two thin bars joined to it. These were formed by the metal which filled the holes X and Y. They can be cut off and the metal made smooth.

Many useful things are made by casting iron : cooking pots, water pipes, parts of ovens, posts for electric lights in a street, parts of engines, and so on. Such things are not made at the iron-smelting factory but in another factory. In this factory the iron must be melted again so that it can be poured into the sand moulds. You would be most interested to visit such a factory and see men pouring white-hot iron from a big " spoon " or from a bucket into a small sand mould in a box or into a big mould built on the floor. There is a picture of the inside of one of these factories on p. 75.

We must remember that cast-iron is brittle. A hard knock may crack it or even break it. We cannot make very strong things with cast-iron. When men made iron in a little clay furnace with a charcoal fire, the iron was fairly pure. The fire was not hot enough to melt the iron so that impurities did not dissolve in it. This iron could be made soft by heating and then be shaped by hammering. Such iron can be made from cast-iron by getting rid of the impurities. Because things can be



(*Photo : Fox Photos*)

A bar of white-hot steel being shaped in a factory.

made from this iron by " working " (hammering, pressing, etc.) we call it " wrought " iron. (" Wrought " is an old-fashioned word which means " worked " ; we seldom use the word now unless we are talking about iron.) A hundred years ago, or even less, much wrought-iron was made from cast-iron by getting out the impurities. It was used for making chains, ships, bridges—in fact, any metal thing which must be strong. Now, little wrought-iron is made. Why ? Because men can make another metal, which is just as strong and useful, more easily. That metal is steel.

CHAPTER IX

AS STRONG AS STEEL

WE have already described how important iron is to us. Most of the iron which we use is in the form of steel. We sometimes call a railway engine an "iron horse"; a better name would be a "steel horse." Many ships and bridges are made of steel, so are all our tools (such as knives, spades, and saws). Motor-cars are made of steel. We use steel whenever we want a hard, strong metal.

What is steel? Steel is an alloy of iron and carbon. Let us see how it compares with cast-iron and wrought-iron. Cast-iron contains 2½–4 per cent. of carbon and other impurities. Wrought-iron contains no carbon and only small amounts of impurities. Steel contains up to 1½ per cent. of carbon and no impurities. So steel has more carbon than wrought-iron and less carbon than cast-iron.

The amount of carbon in the steel makes a big difference to the hardness and strength. Steel which contains about 0·3 per cent. of carbon (that is, 3 parts in 1,000) is harder and stronger than wrought-iron. We call it "mild steel." It is used for making nails, "tins," ships, and bridges. Steel which contains about 0·7 per cent. of carbon is hard and very strong. It is used for making things which must be able to withstand knocks and shakes. Such things are railway-engine wheels and cutting tools (chisels) which we hit with a hammer. With more carbon, up to 1½ per cent. for example, the steel becomes even harder but not quite so strong. It is used for making cutting tools such as knives. It can be given a sharp edge. Very hard steel is used for making files and similar tools for scraping wood or metal. We see that the kind of steel is chosen according to the use which is to be made of it. Steels with more than 1½ per cent. of carbon are not much used and, as we know, if there is more than 2½ per cent. of carbon the metal is cast-iron. Fig. 15 shows some of the uses of different kinds of steel.

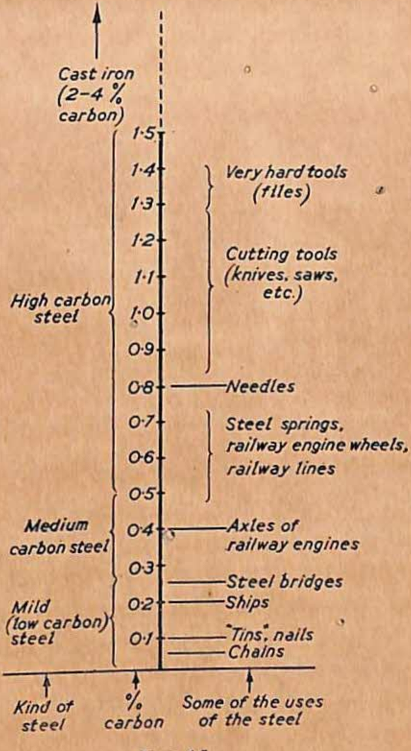
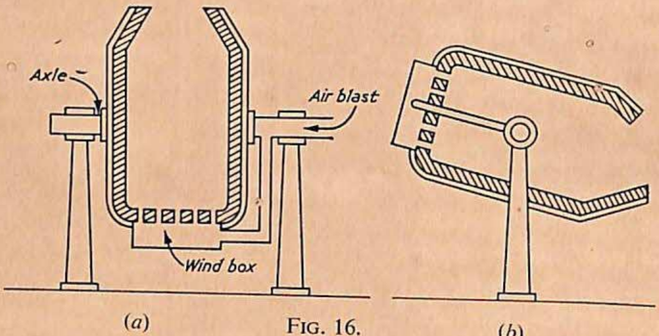


FIG. 15.

About 1856 an Englishman called Bessemer had the idea of improving cast-iron by burning away the carbon and other impurities. He did this by blowing air through melted cast-iron. He found he could not stop the burning at just the right time to leave a little carbon, as needed for steel, but the difficulty was soon solved. The answer was to burn away all the carbon and then add the amount of carbon which is needed. When, by about 1860, mild steel was being made by the Bessemer process, most of the furnaces for making wrought-iron became useless. The new steel was cheaper and stronger.

Let us imagine that we are in a factory where steel is being made by the Bessemer process. We see a big vessel in shape rather like a bottle with a wide, short neck (Fig. 16). It is called a Bessemer "converter" because in it iron is converted, or changed, into steel. It is about 10 ft. across and 20 ft. tall. The outside is made of strong steel plates; inside there is a layer of material which can withstand very great heat. (The layer can be made of silica bricks but, for some purposes, other materials are sometimes used.) The vessel, when holding 30 tons of metal, weighs about 200 tons. At the bottom of the vessel there is a "wind-box" from which many pipes lead through to the inside. The vessel is supported on a level axle. In Fig. 16a the vessel is upright; in Fig. 16b, which shows the view from the side, the vessel has been turned down. The axle on one side is hollow and a pipe joins this axle to the wind-box.



(*a*) FIG. 16. (*b*)

The vessel (or converter) is made hot by burning coke in it, and, after the ashes have been taken out, melted cast-iron (often straight from the blast furnace) put in. Then a strong stream of air is sent through the hollow axle and so through the melted iron. Slowly the vessel is turned to an upright position. First, yellow sparks come out of the top, and then brown smoke and small red-yellow flames. These last for about 5 minutes. Some of the impurities are burning away. Meanwhile the metal in the vessel becomes hotter and hotter. Then, fairly suddenly, there is a great white flame 30 ft. high. The air is making the carbon burn. As the oxides of carbon are gases, they make bubbles in the melted iron so that it seems to be boiling. If you could see this great flame coming from a Bessemer converter you would never forget it. After 10–20 minutes the flame dies down. The stream of air is turned off and the vessel turned to the " down " position.

The vessel now contains almost pure, melted iron, but there is a small amount of iron oxide in it (formed by the

(By courtesy of Stewarts & Lloyds, Ltd.)

A Bessemer converter.

burning of the iron). An iron alloy which contains carbon and manganese (see p. 107) is added. The manganese takes the oxygen from the iron oxide, the carbon joins with the iron to make steel. The melted steel is then run out into moulds. Steel which is made in this way contains, for example, 98 per cent. of iron, 0·4 per cent. of carbon, 1 per cent. of manganese, and small amounts of other substances.

The Bessemer process is not used much in England now because English ores contain an impurity which is left in the steel. There is another way of making steel. It is called the "open hearth process." A hearth is a stone or brick place in which a fire is made. In the open hearth process the melted metal lies as a shallow pool on the bottom of a wide furnace or hearth.

In this method cast-iron, bits of old steel, and iron ore (iron oxide) are melted together on the hearth. The surface of the hearth is made of sand or limestone. The oxygen from the iron oxide joins with the impurities in

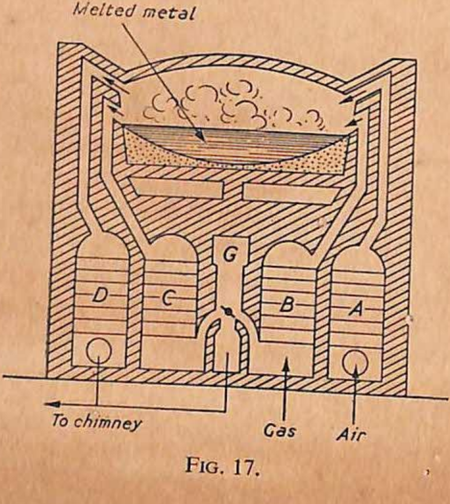


FIG. 17.

the cast-iron, and then the impurities join with the sand or limestone to make slag. Sometimes just the right amount of carbon can be left. If all the carbon is burned away, more must be added.

The furnace must be big enough to hold perhaps 100 tons of metal. The great difficulty is to make such a furnace very hot. The metal must be made white-hot (1500°–1700° C.). Fig. 17 shows the kind of furnace which is used. The heat is made by the burning of a gas (similar to coal gas), but the gas is made hot before the actual burning takes place. Below the hearth on which the metal is melted there are four places, like small rooms, A, B, C, and D. Each " room " contains bricks with plenty of spaces between them. The gas goes in, at first, through B (the pipe which brings it actually comes to G) and air through A. The gas mixes with the air when it reaches the hearth and burns there. The waste gases then pass through C and D before they escape up the chimney. (You can see in the drawing the way the gases go.) These waste gases are hot, and they make the bricks in C and D hot. After a time, the direction of the flow is changed. The gas is made to go through C into the furnace, the air through D, and the waste gases to come out through A and B. Now you can see that the gas and air, by passing between the hot bricks in C and D, are heated before they reach the hearth. At the same time the waste gases are heating A and B. Later, the direction of flow is changed back again, and so on. In this way a very hot furnace is made.

The open hearth process is slower than the Bessemer process, and more costly, for fuel is used in making the gas. But better steel is made this way.

Buckets, bridges, knives, spades, and pins may all be made of steel but, of course, they have different shapes.

We have learned that metals can be shaped by casting (pouring melted metal into a mould) or can be wrought (shaped by hammering, pressing, etc.). Some steel things are made by casting. These are things of awkward shapes like the middles of railway-engine wheels, the hooks which join one part of a train to another, and the back axles of motor-cars. Most steel things, however, are made by hammering and pressing.

The picture on p. 77 shows a piece of hot steel being hammered into shape. The "hammer" is a great steel block weighing several tons. It is lifted by steam power. It falls, or is pushed down by steam, and hits the hot steel. Gradually the steel is hit into the shape which is needed. Shaping by hammering is not a good way of making big things. The hammer shapes the outside of the steel but has little effect on the middle of the steel. It is better to use a "press." The press is a machine which does not hit the steel like a hammer but slowly and strongly presses it into shape.[1]

There is another way of shaping metal. Think of one of the rails on which a train runs. It has the same shape all along its length. Many things are like this: round bars, flat strips, bars for building bridges, and so on. These are made by "rolling." Look at Fig. 18a. A and B are two strong, steel rollers. There is a small space between them. A steam-engine drives them round in the directions shown by the arrows. C is a hot steel bar. It is thicker than the space between the rollers. The rollers pull it between them, so that it moves towards the right, and press it so that it becomes thinner. The bar can next be passed between two rollers which are closer and so be made thinner still. In this way a thick

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[1] You can read more about presses in *Machines and Engines* in this series.

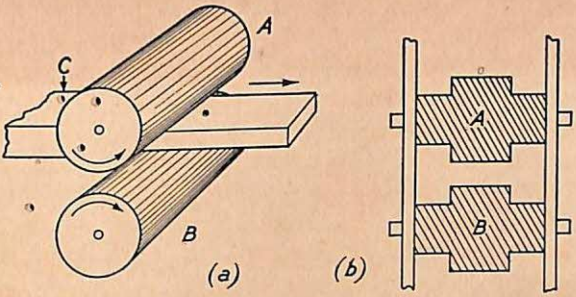


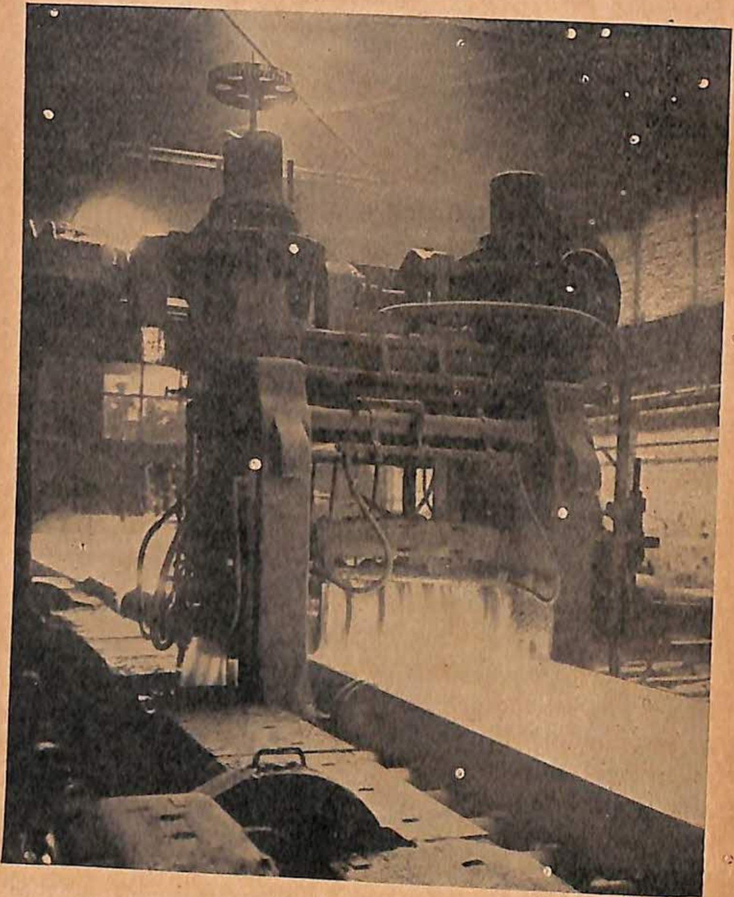
FIG. 18.

bar can gradually be rolled into a thin sheet. Fig. 18b shows two rollers A and B which are not flat. The bar is not only made thinner, it is pressed into a certain shape. By using rollers of the right shapes, round bars, I-shaped bars, and so on, can be made.

Railway lines are made in such a way. A hot, shining block of steel, weighing about a ton, passes several times between rollers which make it longer and thinner. A second set of rollers makes it longer and thinner still. A third set of rollers gives it its proper shape. The block of steel is changed into a rail 50 yards long. It is then cut into pieces of suitable lengths and left to cool.

Steel, we have learned, consists of iron with a small amount of carbon. For many purposes small amounts of other metals are added, so making steel-alloys. The metals which are added are rather uncommon ones; they are not often used by themselves for making things, and some, probably, you have not heard of before.

One of the first steel-alloys which was made contained a small amount of nickel. (This metal, which is used in some countries for making coins, looks something like silver.) It can withstand knocking and shaking. It is used for axles and other parts of machines which move



(*Photo : Fox Photos*)

Rolling steel bars.

quickly and shake about. Some steel-alloys contain both nickel and another metal called chromium. (This is a bright, shiny metal; metal things are sometimes covered with a thin layer of chromium to make them look nice (page 108). Nickel-chromium steel alloys are very hard. They are used, for example, for making the sides of battleships. One kind of nickel-chromium steel is called "stainless steel." It does not rust easily nor become stained (discoloured) by other materials. Knives are often made of stainless steel. Food does not stain them. Another very useful steel-alloy contains 5–13 per cent. of manganese. It is a tough, hard alloy which does not wear away. It is used for making rock-breaking tools and the "points" where railway lines cross or

(By courtesy of Australian News and Information Bureau)

Sydney Harbour bridge. This great steel bridge, 1,650 ft. long, carries four electric railways, a wide road and two footways.

branch. Although many trains pass over the points the lines last for many years. Another hard, tough alloy contains tungsten. (The wires in electric lamps are made of tungsten.) The alloy is used for making cutting tools.

CHAPTER X

ALUMINIUM

IN what way is an aeroplane like a cooking pot? You may well wonder if indeed they are alike in any way. Well, let us see.

Cooking pots have been made of various kinds of substances. Some are made of baked clay, some are made of copper or iron. But, particularly in some countries such as England, cooking pots are often made of another metal. I have a good, strong pot which holds about ½ gallon of water. It is a shiny, grey-white colour. I pick it up. It is very light in weight. It weighs less than a pound. A similar pot made of iron would weigh three pounds. This light, grey-white metal is called aluminium. Now aeroplanes must be strong but they must also be light in weight. Wood is not strong enough, steel is too heavy. Aluminium is both strong and light. Aluminium (and its alloys) is very suitable for the making of aeroplanes. The answer to our question is now clear. Both are often made of aluminium.

Aluminium is a very common element in the rocks. The table on p. 8 shows that only two elements (oxygen and silicon) are more common. It forms part of many igneous rocks (such as felspar and mica), certain jewels (such as red rubies and green emeralds), and, particularly, the various kinds of clay. A field of clayey soil contains tons of aluminium. Yet seventy years ago very few people had even seen the metal. It is not hard to understand why this was so. The aluminium compounds in clay and similar rocks are very complicated and there is no successful way of getting the aluminium from them.

We now obtain aluminium from an ore called "bauxite." (The ore was first found in Les Baux, in France, and it was named after this place.) It consists chiefly of aluminium oxide mixed with silica, water, and often a little iron oxide. It is sometimes dirty white or grey in colour, but the iron oxide may make it yellow or brown. Bauxite is now found in several countries of Europe and in certain parts of North and South America. It has also been found in the Gold Coast but as yet little use has been made of this supply.

We have already learned the usual way of getting a metal from its oxide. We heat the oxide with carbon. The carbon joins with the oxygen and sets the metal free. But if we heat aluminium oxide with carbon we do not get the metal. The oxygen is joined so strongly to the aluminium that the carbon cannot take it away. A science teacher in America once told his class that if anyone could invent a way of producing a good supply of aluminium he would not only become rich but also greatly help mankind. That was in 1885. A few months later, one of the young men in the class found out how to do it. His name was Charles Hall. Within a few years aluminium became a common metal and now more than a quarter of a million tons of aluminium are made every year in the way that Hall had found out.

To understand Hall's method of making aluminium from its ore, we must turn aside to read about one of the powers of electricity. Fig. 19 shows the apparatus which we can use to study the flow of electricity through a liquid. The electricity is supplied from a battery such as a car battery or a bicycle lamp battery. The jar contains the liquid. A and C are two hard carbon rods (like those in the middle of torch batteries) or two metal strips. The rods are joined to the two " terminals " (ends) of the battery

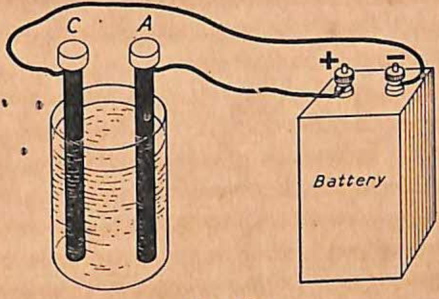


FIG. 19.

by pieces of wire. The current flows from the "positive" terminal (often marked with a + sign or painted red) and comes back to the "negative" terminal (often marked with a − sign or painted blue). The rod which is joined to the positive terminal is called the "anode." It is marked A in the drawing. The rod which is joined to the negative terminal, marked C in the drawing, is called the "cathode." Notice that the rods do not touch. A current can only flow if it can pass through the liquid between the rods.

Some liquids (such as oil) do not let an electric current pass through them. There are two kinds of liquids through which a current can pass. These are (1) solutions made by dissolving certain substances in water, (2) certain melted substances. The best known substances whose solutions let an electric current pass are those called "salts." These are substances like ordinary (common) salt, soda, copper sulphate (sometimes called Blue Vitriol), and Epsom salts (magnesium sulphate). Now this is the important fact. When an electric current flows through such a solution, a chemical change takes place. The compound (salt, soda, etc.) is changed into simpler compounds or sometimes even into its elements. *Usually* *the metal part of the compound is set free at the cathode.* Thus, when a current flows through copper sulphate solution, copper is set free at the cathode. It forms a thin layer of metal on the rod. You can try this for yourself with some copper sulphate solution.[1] Here, then, is a new way of getting a metal from a compound.

Aluminium is obtained from its oxide by an electrical method, but the process is rather more complicated than that which we have just described. Aluminium oxide will not dissolve in water and it cannot easily be melted. The young man Hall found how to overcome these difficulties. There is another ore of aluminium called "cryolite." It is found in Greenland. Hall found that aluminium oxide will dissolve in melted cryolite and that an electric current can flow through the liquid. Aluminium is set free at the cathode and oxygen at the anode. Both bauxite and cryolite, then, must be taken to the factory where aluminium is made. The factory must also have a good supply of electric power. Electricity can be made most cheaply by using the water in a waterfall to drive an engine and so drive an electric generator (machine for making electricity). Aluminium factories, therefore, are usually built in hilly countries where waterfalls can provide the power.

In an aluminium factory, the impurities (silica, iron oxide) are first taken out of the bauxite so that pure aluminium oxide is obtained. The mixture of oxide and cryolite is put in a large container. Fig. 20 shows one of these containers. Compare it with the jar shown in

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[1] The best known salts, such as ordinary salt and soda, contain a metal which cannot be set free in this way. A gas is set free at the cathode instead of the metal. If you try the experiment with a solution of ordinary salt, you can see the bubbles of gas which are formed. This shows that a chemical change takes place.

Fig. 19. Each container is about 14 ft. long, 8 ft. wide, and 3 ft. deep. It is made of steel sheets. The inside (bottom and sides) is covered with a thick layer of hard carbon. This carbon layer is joined to the negative terminal of the electric supply. It forms the cathode; it takes the place of the rod C in Fig. 19. The anode consists of several thick carbon bars joined together. They are joined to the positive terminal of the supply. Very strong electric currents are used.

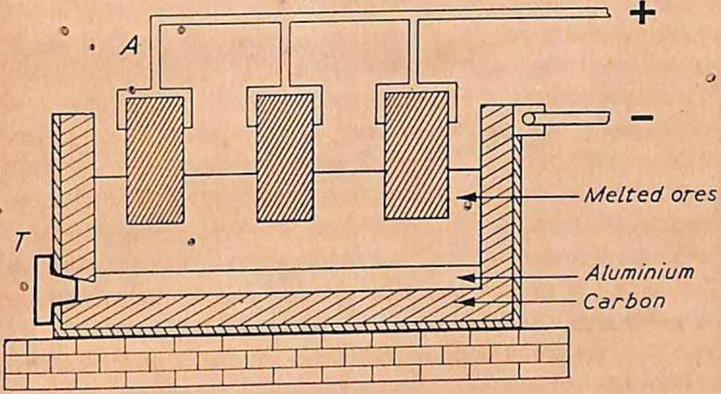

FIG. 20.

Starting with an empty container, a man lowers the anode bars so that they touch the carbon layer at the bottom and then lifts them up again. A hot flame jumps between the bars and the bottom. He throws in some cryolite. It quickly melts. Then he gradually adds the aluminium oxide. The heat caused by the electric current keeps the mixture melted. The aluminium is set free at the cathode, that is, at the sides and bottom of the container. It is melted by the heat. As it is heavier than the melted mixture, it collects at the bottom.

When the tap T is opened it runs out. It is cast into bars. The oxygen from the oxide is set free at the anode. Gradually the anode bars burn away so that, at times, they must be lowered, and, at last, new ones used. The cryolite is not used up. Fresh aluminium oxide is added from time to time.

Aluminium, when fresh and pure, is a silvery-white metal. It does not rust, and chemicals and impurities in the air do not attack it. In Piccadilly Circus (London) there is an aluminium figure of Eros. It has been there for fifty years, but the impure air and smoke from factories have not harmed it. Aluminium protects itself by forming a *very* thin layer of aluminium oxide on its surface. This layer makes the metal dull but prevents air or other substances from attacking it further. We have already learned that it is a very light metal. A piece of aluminium weighs only about a third as much as a piece of iron or steel of the same size. Aluminium is a good "conductor" of heat and electricity, that is, it lets heat and electricity pass through it easily. These three qualities—resistance to air and other substances, light weight, power to conduct heat and electricity—make aluminium a very useful metal.

Aluminium is a very good metal for making cooking pots. The pot does not rust (and spoil the food), it is light in weight (so it is easy for people to lift it and carry it), and it lets heat pass through it well from the fire. In making a pot, the aluminium is first rolled into flat sheets and then round pieces are cut from it. Then each piece is placed in a machine which quickly bends up the edges to make the proper shape. A handle is fastened on and the pot is made. Some food containers are made of aluminium. Very thin aluminium sheets (as thin as paper) have many uses. Aluminium sheet has been used, for example, for wrapping up chocolates and cigarettes.

(*Photo : Fox Photos*)

The aluminium figure of Eros in Piccadilly, London.

It has been used for making a lady's dress. With red ornaments the dress was very pretty.

Aluminium is also used for making wires to carry electricity, particularly the thick wires which, in England for example, are supported by steel towers and carry electricity from one town to another. These wires must be strong, light in weight, and able to carry electricity well. Pure aluminium wire would not be strong enough. Wire is made which consists of aluminium on the outside but with steel along its middle. In England over 13,000 miles of such wire are used.

As aluminium is not very strong, small amounts of other metals, such as copper, zinc, or iron, are often added.

These aluminium alloys do not conduct heat and electricity so well, but they are light in weight and much stronger. The alloys, like most other metals, can be cast (by pouring the melted metal into a mould) or wrought (shaped by rolling, pressing, and so on). Wrought things are always stronger than cast things.

It is impossible to give a list of all the uses of aluminium alloys. Houses have been built of aluminium instead of stone or brick, and almost everything inside made of aluminium—tables, chairs, ovens, window-frames, cooking pots, ornaments, and so on. Small boats, for use on the sea, have been made of aluminium. But the most important uses of aluminium alloys are in motor-cars and aeroplanes. Many parts of their engines are made of aluminium. Think, for example, of the "pistons." (These are pushed up and down in the "cylinders" by the quickly burning petrol and so work the engine.) When a car engine is running, the pistons move up and down 5,000 times in a minute. They must be made of a strong metal and yet one which is light. (It is easier to make a light thing move up and down quickly than a heavy thing.) An aluminium alloy has both these qualities.

One of the best known aluminium alloys is made by adding a little copper (4 per cent.) and smaller amounts ($\frac{1}{2}$ per cent.) of manganese and magnesium.[1] It is called "duralumin." There are also several similar alloys. These alloys are as strong as mild steel but not half so heavy. A fairly thin bar 30 ft. long can easily be lifted with one hand but if it rests on a support at each end two men can safely sit on it in the middle. The alloys are used for making the frames of aeroplanes. The picture on p. 97 shows the making of duralumin aeroplane frames.

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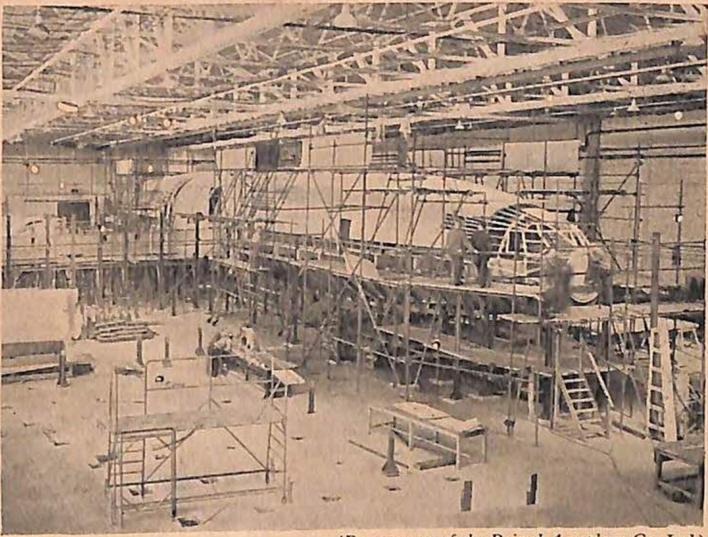
[1] For manganese see p. 107, for magnesium see p. 121.



(By courtesy of the Bristol Aeroplane Co. Ltd.)

Building the aluminium framework of an aeroplane.

Before we leave this most useful metal, aluminium, we must describe another, rather strange, use. We remember that aluminium joins very strongly with oxygen, in fact, for many years men did not know how to separate aluminium from its ores. Suppose we make a mixture of aluminium powder (very small bits of aluminium) and iron oxide, put it in a fire-clay pot, and set light to it. The mixture burns very violently and becomes very hot. Melted iron sinks to the bottom of the pot and, later when it cools, turns into a solid there. The chemical action can be shown shortly like this :

aluminium + iron oxide ⟶ aluminium oxide + iron,

that is, the aluminium takes the oxygen from the iron (so forming aluminium oxide) and sets the iron free. Compare this with the action of carbon and iron oxide (p. 68). Aluminium can be used instead of carbon for getting a metal from its ore. It is too costly always to be used in this way but is useful for certain metals (see, for example, manganese on p. 107).

A mixture of aluminium powder and iron oxide gives a useful way of making very hot, liquid iron. It is used for joining together iron bars which cannot be moved, such as parts of a machine or rails in the ground. Fig. 21 shows how two iron bars can be joined together. A mould, made of fire-clay and sand, is built round the ends of the bars. A pot of aluminium and iron oxide is placed over the top. Notice the hole in the bottom of the pot. At first the hole is closed. The mixture is set alight and liquid iron, far hotter than its melting point, is formed. The workman pulls a lever which opens the hole in the bottom of the pot. The liquid iron runs into the mould. It fills the space between the bars and melts their ends. Afterwards, when the iron has cooled, the two bars have been joined into one. The mould is then taken away.

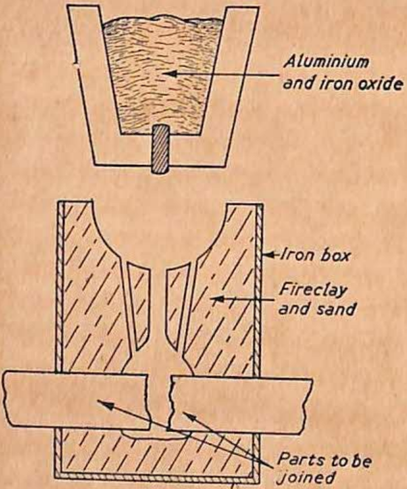


FIG. 21.

There we must leave the story of aluminium. We owe much to Charles Hall. He did become a very rich man, but he gave away a lot of money to help other people.

CHAPTER XI

SOME OTHER USEFUL METALS

YOU will have noticed that each metal has its own particular qualities which make it very suitable for particular purposes. Thus steel is strong, aluminium is light, and so on. Men have discovered many metals and gradually found out the special uses of each. We cannot describe all the different metals in this little book, but we must have a quick look at a few more of the common ones.

COPPER—For electric wires

Get a piece of wire which is used for carrying an electric current. It may be a piece which is used for carrying electricity to an electric lamp, or from inside a motor-car. The wire probably has a rubber or cotton covering on it. Scrape this off. Inside you find a bright, red-brown metal. This metal, of course, is copper. Many coins are also made of copper (or of a copper alloy), but the special use of this metal is for making electric wires.

Copper was one of the first metals used by man. In some countries, big pieces of almost pure copper are found, and men would easily find them because of their shiny, red-brown colour. They found that they could fairly easily beat the metal into useful shapes and so make pots, ornaments and weapons. Then some copper ores are brightly coloured, often green or blue, and men must have noticed them too. They found that they could get the metal (in a rather impure form) from some of these ores by making a fire with pieces of ore and charcoal. We have already described how bronze (the copper-tin alloy) was probably made, first by accident, by using a mixture of copper and tin ores.

Free copper, that is, copper metal and not copper compounds, is found in many places, but particularly near Lake Superior in North America. Pieces weighing several hundred tons have been found. One piece was so big that 20 men took 15 months to break it into smaller pieces and carry it away. Most copper, however, is made from ores. Copper ores are found particularly in the United States, Chile (South America), Canada, Northern Rhodesia, and the Belgian Congo. There are many kinds of copper ores. Some consist chiefly of copper oxide and some of copper sulphide.

The smelting of copper ores is complicated, especially if copper sulphide ores are used. In one method the ore is smelted with coke and sand in a blast furnace. The very impure copper which is so made is then melted in a Bessemer converter (Fig. 16) and air blown through it. The metal, which is now fairly pure, is poured into moulds.

New copper has a beautiful bright red-brown colour but it becomes dull in the air. (You know that copper coins, so bright when they are new, become dull and dark when they are old.) With zinc it forms a very well-known alloy. This is "brass." It has a beautiful yellow colour. We use it for making trays and many kinds of ornaments. Brass is as strong as copper but not so tough. It melts more easily and is very suitable for casting. Brass parts in machines, however, are more often "wrought." Pure copper can be shaped fairly easily. It can be rolled into sheets less than $\frac{1}{500}$ inch thick, pulled into thin wires, and pressed and beaten into complicated shapes without cracking.

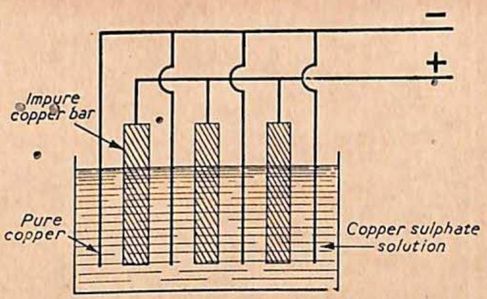
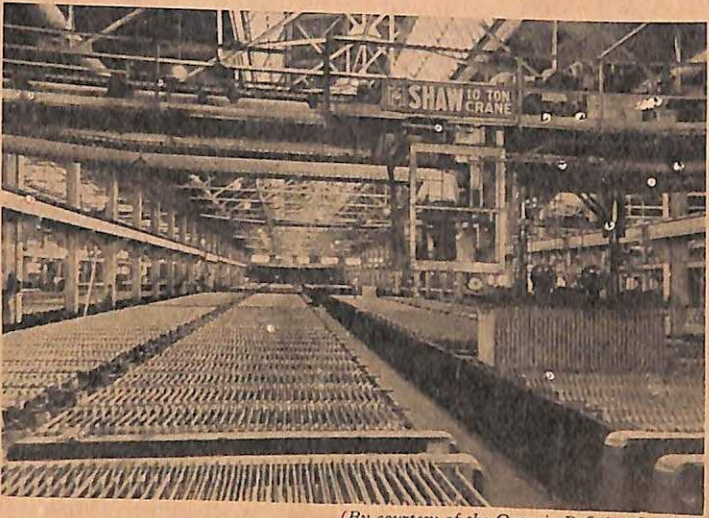


FIG. 22.

Copper is a very good conductor of heat and electricity. Only one metal, silver, is a better conductor. Silver would be too costly for making electric wires and machines, and copper is therefore the best metal for the purpose.

The copper which is made for other uses is not pure enough for electrical purposes. It must be made very pure. The impure metal is cast into bars 2–3 inches thick. They are hung in a container of warm copper sulphate solution. Thin sheets of pure copper are hung between the bars (Fig. 22). All the bars are joined to the positive terminal of an electric supply. They are therefore anodes. The pure sheets are joined to the negative terminal and so form cathodes. When the current flows, copper from the solution is set free at the cathodes (compare aluminium). Gradually a thick layer of pure copper is formed. At the same time the anodes are eaten away. The copper in them dissolves in the liquid but the impurities fall to the bottom. So really copper is taken from the anodes, separated from the impurities, and put on the cathodes. Very pure copper is made in this way. About ¾ million tons of copper are used every year for making various electric wires and machines.



(By courtesy of the Ontario Refining Co. Ltd.)

Making pure copper by electricity. Notice the row of plates on the right which have been lifted from the containers.

ZINC—The protecting metal

Iron and steel are very useful metals but they have one big disadvantage. They rust in damp air. An iron roof of a hut soon rusts and even if we use " tin-plate " (as in ordinary " tins ") the tin does not protect the iron for long. In my garden there is a hut made of " galvanised iron." The sheets of metal are curved into small " hills and valleys " so that they are stiff and fit well together, but, of great importance, the iron does not rust. The iron is protected by a very thin layer of another metal. That metal is zinc. Buckets and other containers are often made of galvanised iron.

We also meet zinc in another way. If you take an ordinary " dry " electric battery, like that used for a torch or a bicycle lamp, and take off the paper covering, you find that the outer container of the battery itself is made of a grey-white metal. This, again, is zinc.

The most common ores of zinc consist of zinc sulphide. They are found in many countries but particularly in the United States, Australia, Canada, Germany, and Mexico. The ores are heated in the air and so changed into zinc oxide. There is one unusual difficulty in getting zinc from its oxide. Zinc *boils* fairly easily. As you can see from Fig. 8, the *boiling* point of zinc is lower than the *melting* point of cast-iron. The zinc actually turns into vapour (just as water turns into steam). So if zinc oxide and carbon are heated in a furnace, the zinc which is set free turns into vapour. Unless special arrangements are made to collect the vapour, it will escape with the smoke.

Most kinds of furnaces for smelting zinc use the idea shown in Fig. 23. The furnace consists of a row of fire-clay vessels R. The mixture of zinc oxide and coal is put in these vessels and heated by burning gases. An iron container C is joined to each vessel R. These containers are outside the furnace and therefore cooler. The zinc vapour passes into these cooler containers and turns back into liquid zinc. The liquid zinc is run out and cast into solid blocks. The zinc obtained in this way is not pure but is good enough for ordinary purposes. It can be purified, if necessary, in a way similar to that used for copper.

Zinc is a very useful metal. Sometimes roofs of huts and railway stations are made of sheets of zinc. Pure zinc

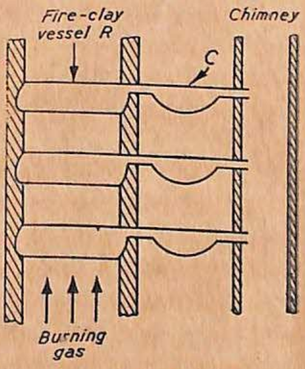


FIG. 23.

roofs do not rust and they last for many years. Strips of zinc are used on slate roofs at corners and other places where water might get through. But the most important uses of zinc are for making brass and for "galvanising" iron.

Iron sheets are galvanised by dipping them into melted zinc. The zinc forms a thin layer all over the iron. Unlike tin-plate, the iron does not easily rust if the layer of protecting metal cracks (but does so if, after a long time, the zinc wears away). In many parts of the world, where slates and tiles are expensive or difficult to obtain, galvanised iron sheets are used for roofs of all kinds of buildings. The roofs do not look very nice, but they are light in weight, easy to fix, and last for many years.

Most iron things which are to be used outside where they may get wet are galvanised. The farmer uses galvanised wire and galvanised netting to put round his fields. On a boat we find that hooks, bolts, rings, and similar fittings are galvanised. The big wire "ropes" used for tying a ship in port and the anchors (dropped to the sea-bottom to keep a ship still) are galvanised. Zinc is used to protect iron buckets, certain steel parts of aeroplane bodies, springs, nuts and bolts, and hundreds of other useful things.

LEAD—The metal with many hidden uses.

When a diver goes down into the sea, to mend the bottom of a big ship, he puts on a special rubber suit. The suit covers his head, and air is pumped to him through pipes. The bottoms of his boots are made of lead. They weigh about 16 lbs. each ! Then two lead plates are fixed to him, one on his back and one on his chest. These weigh about 40 lbs. each. These weights keep him on the sea-bottom and hold him steady. Without them he would float to the top like a cork.

Heaviness, then, is an important quality of this metal. When people wish to say that something is very heavy they sometimes say it is "as heavy as lead." Although lead is the heaviest of the common metals, several metals are heavier. Turn back to Fig. 7, p. 43. We see that lead is about 11½ times as heavy as the same volume of water. Iron is about 8 times as heavy. But gold (which we do not often see in big pieces !) is nearly 20 times as heavy as water.

The chief lead ore is lead sulphide. It is found in many countries but especially in the United States, Australia, and Mexico. Not much is dug up in England now but about 2,000 years ago the Romans obtained most of their lead from England. Lead ore often contains some silver and much of the world's silver is obtained in the purifying of lead. The lead is obtained from its ores in various ways. In one way the ore is heated in a furnace (like that shown in Fig. 11) through which a stream of air is blown. Lime is then added. It forms a slag with the rock waste. The melted lead is run out into pots.

A new-cut surface of lead shines like steel but air soon makes it dull. It does not rust, however, and is not eaten by acids. Although it is so heavy, it is very weak and soft. You can bend a sheet of lead with your fingers. The ease with which it can be shaped, and its resistance to rusting, make lead useful in many ways.

Water pipes are often made of lead. The Romans made lead pipes 2,000 years ago. Lead pipes do not rust and spoil the water and they last for many years. The Roman (Latin) name for lead was "plumbum." We call a man who is skilled in fixing and mending lead pipes a "plumber." Lead sheets have been used for making roofs, but they are rather heavy and are only suitable for strong buildings. Many old churches in England have lead roofs. Lead is also used for making containers for acids and for covering electric wires.

Another important use of lead is for making bullets and "shot" for guns. Have you wondered how the little balls of shot are made? They are not made in moulds; that would be too slow and costly. The lead (often mixed with a little of the metal antimony) is melted at the top of a tower about 150 feet high and put into a container which has small holes in the bottom. The melted lead runs through the holes and falls to the ground. As it falls, it breaks up into little drops like "lead rain." Each drop becomes round as it falls. The drops fall into a container of cold water at the bottom of the tower and immediately form solid round balls.

About a million tons of lead are used up every year, but we do not often realise how useful it is. We have described the lead-tin alloy called solder. Another useful alloy is made from lead and antimony. The alloy is used for casting the letters with which a book is printed. A big amount of lead is used in electric batteries like those in motor-cars. Much is used in making paint. The lead is changed into a compound called "white lead." Paint which contains white lead, as well as the colouring material, forms a good thick coating and wears well. There are many more uses which we have not room to describe.[1] Lead is the metal with many uses in hidden ways.

MANGANESE—For making steel

There are some metals which ordinary people never see and yet alloys which contain them are common. One of these metals is manganese. Nothing is made of pure manganese but most kinds of steel contain it. So manganese is an important metal.

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[1] But lead is not used in pencils. The "lead" of a pencil consists of carbon and clay.

Manganese ores consist chiefly of manganese oxides. Much of the ore is found in Russia but useful amounts are found in India and West Africa. At Nsuta, in the Gold Coast, there is a large amount of ore in the hills. The ore is near the surface so mines need not be made (see the picture on p. 49). The rock, which is dug out from the hill-side, is carried away in railway trucks to places where it is "washed." There great streams of water are used to wash away the useless rock from the ore. The ore is then taken to Takoradi, the port, put on a ship, and taken to Europe.

The metal can be obtained from the ore by heating it with carbon but a very hot furnace must be used. Aluminium is generally used instead of carbon. The ore is first heated and then mixed with aluminium powder. The mixture is put in a fire-clay pot and set alight. It burns violently and the manganese is set free. Much manganese is used in the form of an iron-manganese alloy. This is made by heating the ore with iron oxide and carbon in a blast furnace.

We read on p. 82 how the iron-manganese alloy is used in the Bessemer process of making steel. The manganese helps to take away certain impurities (chiefly oxygen and sulphur compounds), but, although this is its main purpose, a little manganese in the steel makes it stronger. All ordinary kinds of steel contain about ½ per cent. of manganese. A very hard steel alloy is made by adding about 13 per cent. of manganese (p. 87). It is used for making rock-cutting tools and the "points" on railway lines.

CHROMIUM—Also for steel and for electro-plating

The front of my motor-car is bright and shiny and it never becomes rusty, stained, or spoiled by the weather. In my house there are many metal things—such as coat-pegs, trays, ornaments, and even my pocket watch—with this bright, shiny surface. They have been "chromium-plated." They are made of iron, or other cheap metal, but on the surface there is a "plating" (very thin layer) of the metal chromium. Although this is the best known use of the metal, it is not the most important. Large amounts of chromium ore are used in making a special kind of brick for furnaces and even larger amounts are used in making various kinds of chromium-steel.

Chromium ore consists chiefly of chromium oxide and iron oxide. Most of it is found in Russia, Turkey, Southern Rhodesia and South Africa. It is interesting to notice that none of the big steel-making countries, except Russia, has its own supplies of chromium. They have to depend upon supplies from other countries. Chromium, like manganese, is obtained by heating a mixture of its oxide and aluminium powder in a fire-clay pot. An iron-chromium alloy is used for steel-making. This is made from a mixture of iron oxide and chromium oxide (as found in the ore) either by heating it with aluminium or by heating it with carbon in an electric furnace.

Steel which contains a small amount of chromium is very hard. A steel which contains 1 per cent. of carbon and $2\frac{1}{2}$–4 per cent. chromium is so hard that ordinary tools cannot cut holes in it. It is used for making bank "safes" and railway "couplings" (hooks, etc.). We have already described some of the many important uses of nickel-chromium steels (p. 87). Another important alloy consists of about 20 per cent. chromium and 80 per cent.

nickel. It is called Nichrome. It conducts electricity only moderately well, and so becomes hot when an electric current is passed through it, but it does not melt easily or spoil with the heat. It is therefore much used for making the heating wires in electric ovens, " fires," and similar things.

We see the pure metal on things which are chromium plated. The plating is put on by an electrical process and so we call the process " electro-plating." We read in Chapter X how electricity can cause a chemical change to take place in a solution of a salt so that the metal part of the salt is set free at the cathode. If a current passes through a solution of a chromium salt (such as chromium sulphate), chromium is set free at the cathode. In chromium plating, the thing which is to be plated (e.g. the tray) is used as the cathode. Then the chromium which is set free forms a thin layer on it. The actual plating, though hard, is very thin, and so the thing is nickel-plated first. The chromium protects the cheap metal from which the thing is made and its bright surface is very pleasing.

The name " chromium " tells us something more about this important metal. It comes from a Greek word which means " colour." Most chromium compounds are brightly coloured, usually red, orange, or green. Some of these compounds are used, as you might expect, in making dyes and paints, and as colouring material in glass and pottery.

There are many kinds of steel-alloys, each with a special use, and we cannot describe them all. We will end by reading about " high speed steel." In some factories there are machines for cutting metals. The cutting tools in these machines move very fast and become very hot. Now many steel tools lose their hardness or break when they become hot. High speed steel is a complicated alloy which contains (as well as the carbon) chromium, tungsten, and a very uncommon metal called vanadium. A tool made of this alloy can make a hole ¾ in. wide through a cast-iron bar 2½ ins. thick in 8 seconds. (Now you see why the alloy is called “ high speed ! ”) And it can continue cutting at this speed for hours, even if its end becomes red-hot.

CHAPTER XII

JEWELS

HAVE you seen a diamond? It looks like a small piece of clear glass, but it shines in the light and gives flashes of different colours. People use diamonds as ornaments. Sometimes they are fixed to a gold ring and worn on the finger. There are also other kinds of jewels. Rubies are beautiful red jewels and sapphires are blue. Other jewels are green or purple. Topaz is often yellow or brown but some kinds of topaz are white and look like big diamonds. Most jewels, of course, are very valuable.

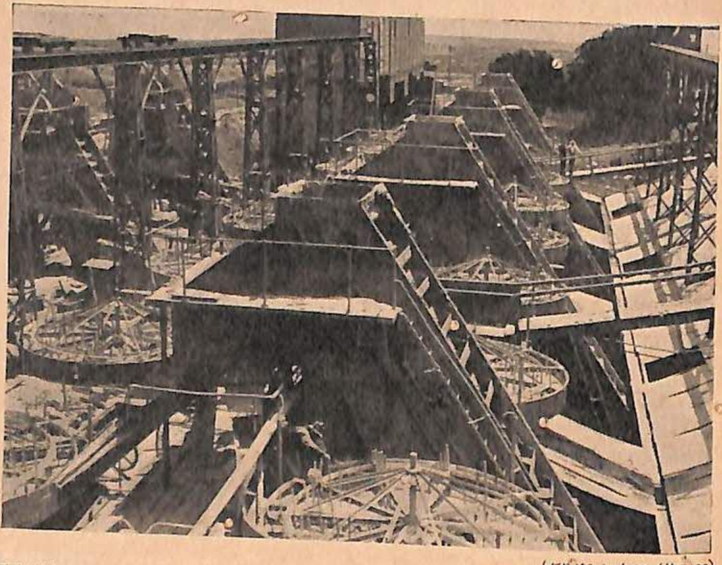
All jewels are very hard. A diamond is the hardest substance known. Because they are hard, jewels cannot easily be scratched, and they do not wear away.

Most people now think that diamonds are the most beautiful jewels, but, long ago, people did not think so. When a diamond is dug up from the ground it is not very beautiful. But men have found out how to cut and shape a diamond so that it flashes in the light and now we sometimes call it the Queen of Jewels.

Diamonds were first found in certain river gravels in India. Later they were found in Brazil (South America) and, nearly a hundred years ago, in the gravel which forms the sides of the Vaal River in South Africa. We can guess, from what we have read about gold and tin, that the diamonds which are found in river gravel have been washed out of the older rocks in the hills. Next diamonds were found in the easily-broken, yellow "sub-soil" in certain parts of South Africa. ("Sub-soil" is the layer of rather hard soil below the ordinary soft soil in which plants grow.) Men dug deeply into this sub-soil and found that there was a blue rock below it. They spread this rock out on the ground in fields, so that rain and sunshine could reach it, and it gradually became yellow like the sub-soil. The yellow sub-soil (which contains the diamonds) was made from the blue rock. Now very deep mines have been made and diamonds are obtained direct from the blue rock.

In 1919 some scientists were examining the gravel near the Birim River in the Gold Coast and found a diamond. Since then, many diamonds have been found in the gravel of the smaller rivers in the Birim valley, and, in smaller numbers, in many other parts of the country. Recently diamonds have been found in Tanganyika.

Diamonds are very rare. Only a few are found in



(Photo: Fox Photos)

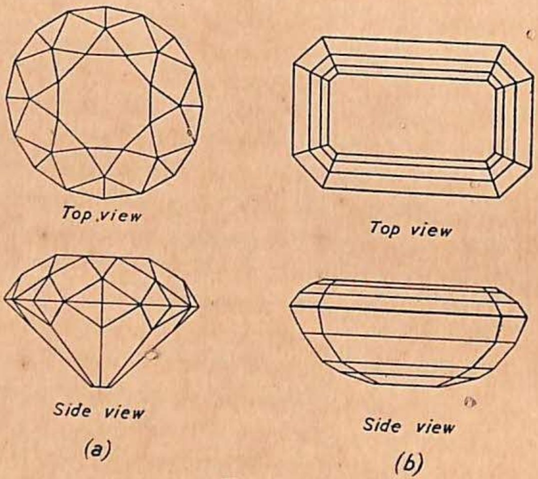
Washing machine at the Premier Diamond Mine, Pretoria (South Africa).

much gravel or clay. The gravel is dug up and carried in trucks to "washing" machines. In these machines, streams of water wash away the sand and mud and leave behind the coarse gravel and (perhaps !) diamonds. Then the gravel is put into boxes which are made to jump up and down and clean water is passed into them. The diamonds, which are heavy, sink to the bottom but the gravel is carried away with the water which runs out of the tops of the boxes. There is another way of separating diamonds from the gravel. After the sand and mud have been taken away, a stream of water carries the gravel down a sloping iron plate. The plate is covered with grease. The diamonds (if there are any) stick to the grease but the gravel is carried away by the water.

By now you may be wondering what diamonds are made of. The answer is very surprising. Diamonds consist of carbon. But, you will say, carbon is a black substance; coal consists largely of carbon. That is true. A diamond is a carbon *crystal*, and, strange as it may seem, the crystals are white. We do not know exactly how diamonds have been formed in the rocks. Perhaps, deep down below the surface, some carbon was melted by the heat and, under great pressure, it formed a crystal when it cooled. A French scientist once tried to make diamonds by dissolving pure carbon in melted iron and then cooling the iron very quickly. To his delight he succeeded in making a few diamonds but they were very small. The cost of making diamonds in this way is more than the value of the poor diamonds which are obtained.

Diamonds are sorted according to their size, shape, and colour. (Some diamonds are slightly coloured by impurities.) They are sold by weight. Some very big diamonds have been given special names. The famous

Koh-i-noor diamond, found in India, weighs over $\frac{3}{4}$ oz. The biggest diamond so far found came from a South African mine. It weighed about 22 ozs.! Two fine jewels, each bigger than the Koh-i-noor, were made from it, and more than a hundred smaller jewels.



(a) (b)

FIG. 24.

In making jewels, the diamonds (or other stones) must be cut to certain shapes and polished. The shapes are such that the jewels show their colours well and shine in the light. Fig. 24 shows two shapes which have been found to be very suitable. Diamonds are usually cut to shape (a) and coloured jewels (such as rubies) to shape (b). Great skill is needed to cut jewels properly and many valuable jewels have been spoiled by bad cutting.

If you hold a diamond, such as one in a ring, so that sunlight or light from a lamp falls on it, it shines brightly and, as you move it, gives flashes of red, green, blue, and other colours. Fig. 25 shows why it does so. Ordinary

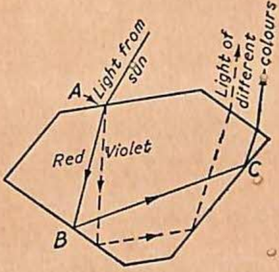


FIG. 25.

light, from the sun or a lamp, is really a mixture of colours. The chief colours are red, orange, yellow, green, blue, and violet. We do not usually see these colours because they are all mixed together. In Fig. 25, a ray of ordinary light falls on the top of the cut diamond at A. It bends a little as it goes into the diamond, but, more important, *light of each colour is bent by a different amount.* Red light is bent least, violet light most, and other colours in between. So the colours of the light are separated. The rays of different colours are reflected by other sides of the diamond, as at B and C, and come out again. When you move the diamond about, rays from the sun or lamp hit the top in various ways, and rays of different colours come out at all sorts of angles. Hence the diamond flashes brightly.

Many people know that diamonds are valuable jewels but do not realise that they have other important uses. As we read earlier, a diamond is the hardest substance known. Because of this, a diamond can cut and scratch all other substances and itself is not worn away. Diamonds which are useless for jewels, because they are small or of bad colour, are used in many ways. Some are used for making glass-cutting tools and others put on the ends of rock-cutting tools. Wheels which are used for grinding and polishing metals have diamond "dust" on their edges, and the dust is also used for cutting and polishing the bigger stones used as jewels.

Very thin wires, like those in electric lamps and those which form the springs of pocket watches, could not be

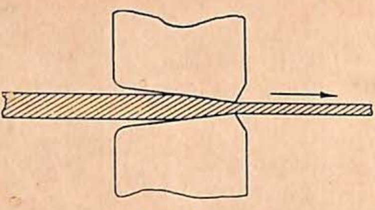
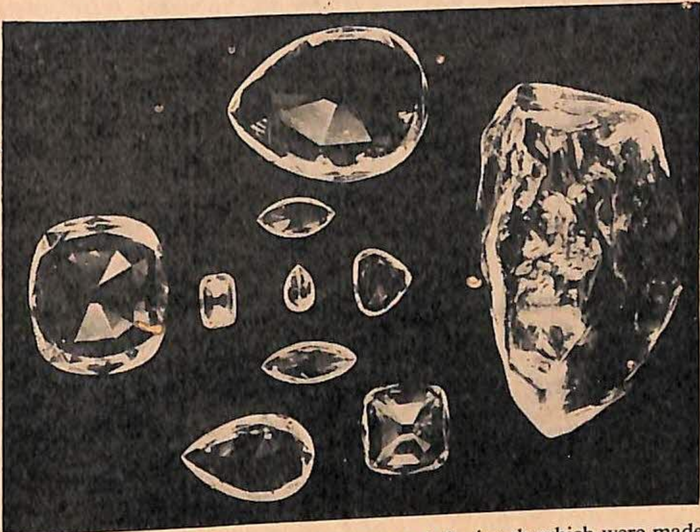


FIG. 26.

made without diamonds. Wires are made by pulling a thin rod of metal through a very small hole. Fig. 26 shows the idea. The rod is pulled through smaller and smaller holes so that it becomes thinner and thinner. The metal rubs very hard on the sides of the hole, and tends to make the hole bigger. So a hole is made through a diamond and the diamond then fixed in a frame. The rod is pulled through this hole, but, because the diamond is so hard, it does not wear the sides of the hole.

Some people like coloured jewels better than diamonds. All jewels are hard rock crystals. The colours are caused by *very* small amounts of impurities (usually metal oxides). Aluminium oxide is sometimes found as small crystals. These crystals, if quite pure, have no colour. If they are coloured red (by a small amount of chromium oxide) we call them rubies ; if they are coloured blue (probably by a small amount of titanium oxide) we call them sapphires. As aluminium oxide is a fairly simple substance, it is not surprising that men have tried to make rubies. Pure aluminium oxide is melted by a very hot flame so that it forms a little drop. A little chromium oxide is added to give the colour. When the drop cools and becomes solid it looks exactly like a real ruby. Another well-known jewel is called topaz. It is often found in the river gravel which contains tin ore. It is found, for example, in Nigeria. Usually it is coloured yellow or brown, by small amounts of iron oxide, but white topaz, when cut to shape, makes a fine jewel. It looks almost like a diamond.

All jewels are hard, and, like diamonds, are used in making tools for grinding and cutting. There are usually some jewels in a pocket watch. They form the supports for the little axles. Although the axles turn thousands of times in a year they do not wear the jewel supports. Small or poor jewels are used for such purposes, or, quite often, jewels which have been made artificially.



Models of the Cullinan diamond (right) and the jewels which were made from it. The diamond weighed 22 oz. and measured 4″ × 2½″ × 2″.

CHAPTER XIII

TREASURES FROM THE SEA

THE seas cover about three quarters of the Earth's surface. Some seas are deeper than others. The deepest sea is near some islands between Asia and Australia. There the sea is about 6 miles deep. *On the average* the seas are about 2 miles deep. This great amount of water contains many useful materials.

Sea water has a bitter, salt taste. If we take some sea water and boil it carefully, so that all the water turns into steam, a dirty white powder is left. Most of this powder is ordinary salt. From 100 lbs. of sea water we get about $2\frac{3}{4}$ lbs. of salt and about $\frac{3}{4}$ lb. of other materials. Scientists have examined this other $\frac{3}{4}$ lb. Much of it consists of compounds of magnesium and potassium, about which we shall read more later, but there are also small amounts of many other compounds. All of these compounds are dissolved in the water. There are even very small amounts of gold.

It is not surprising that the seas contain many kinds of materials. The streams and rivers wash materials off the land and carry them into the seas. There is not much salt in river water (you cannot taste it) but the seas have received materials from the land for perhaps millions of years. Some of the materials fall to the sea bottom, some are used by the plants and animals which live in the sea, and others remain dissolved in the water.

The amount of sea water which would fill a bucket contains only a very small amount of each material. But the seas are so big. Try to imagine the water in a part of the sea which is 1 mile long, 1 mile wide, and 1 mile deep. This is a very big amount of water although it is only a small part of the seas. This amount of water contains about 177 million tons of salt, 5 million tons of magnesium compounds, large amounts of other materials, and even 23 tons of gold.

Why, then, do we not get these useful materials out of the sea? In the last few years certain materials have been obtained from the sea. But from millions of tons of water we only get a few pounds of useful materials. The cost of the machines and of the work which has to be done may be more than the value of the material. Gold, for example, has been obtained from the sea, but the cost of getting it is more than the value of the gold. So, until most of the ores in the ground have been used up, little use will be made of the materials in the sea. In this chapter we shall read of the few materials which are already obtained from the sea.

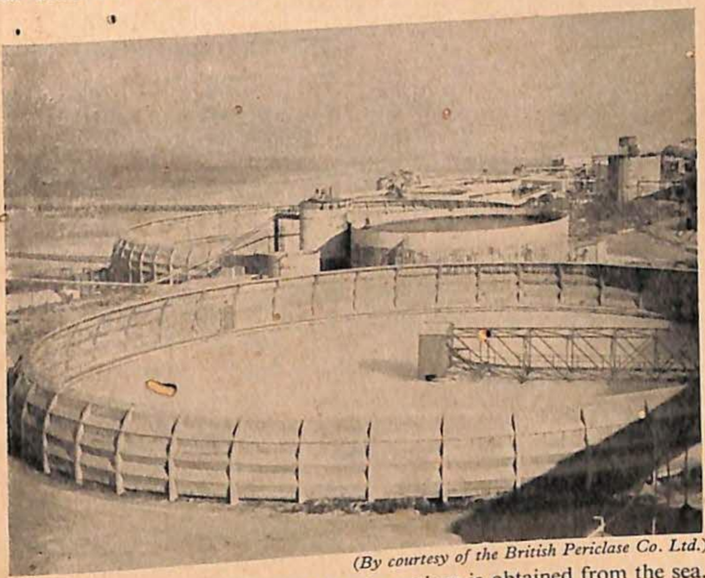
Ordinary salt is a very important material. Men and animals need small amounts of salt in order to keep healthy. Great amounts of salt are used in the making of many important chemical substances. Soda is made from salt. It is used for washing and in the making of soap and glass (p. 19). Another important substance which is made from salt is called caustic soda. This is used in the making of artificial silk and paper. Yet another important substance is a gas called chlorine. This is used to take the colour out of paper and cloth, and to kill disease germs in water.

In parts of England, and certain other countries, there are large amounts of salt in the ground. Scientists believe that the salt came from seas and salt-lakes which dried up a very long time ago. This salt can be dug up from mines. More usually, water is allowed to flow into the mines. It dissolves the salt and is then pumped out. The salt water is then boiled to drive away the water and so leave the salt. In other countries salt must be obtained from the sea. Often shallow lakes are made near the sea and sea water run into them. (In some places, such as parts of West Africa, there are natural sea-water lakes near the shore.) In the dry seasons the water of the lake evaporates and leaves a layer of salt on the bottom.

In England the salt in the ground is fairly pure. In Germany there are also great layers of similar materials. These are chiefly compounds of magnesium and potassium. These materials, too, were probably formed from a sea which dried up long ago. For many years, most of the world's supply of these compounds came from these layers.

In 1924 men began to try to get materials (other than salt) from the sea. They wanted compounds of an element called bromine. You may never see this unusual element. It is a red-brown liquid which easily turns into a red vapour. Its chief compounds are called bromides. Bromides are used in making photographs, certain kinds of medicine, and certain dyes. Other bromine compounds are often put into petrol. It was for this last purpose that men decided to try to get bromine from the sea and not to depend upon the bromine compounds which are found in the German rocks.

First scientists had to find out how to get the bromine compounds from the sea water. Then engineers had to find out how to build the necessary machines. About 4,000 gallons of water must be used to get 1 lb. of bromine. A factory for making bromine uses several million gallons in a day. This great amount of water must be pumped from the sea, any sand and mud must be taken out, and, after the bromine compounds have been obtained, put back into a different part of the sea (so that it is not used again). All of this must be done cheaply. Several factories for doing this have now been made and thousands of tons of bromine are obtained from the sea every year.



(By courtesy of the British Periclase Co. Ltd.)

General view of a factory at which magnesium is obtained from the sea. Notice the pipes (left) leading in from the sea.

Next scientists tried to get magnesium compounds from the sea. Magnesium is a metal. (Do not mistake magnesium for manganese.) It is even lighter than aluminium but as strong as steel. If you hold a piece of magnesium wire in a flame it catches alight and burns with a very bright light. Thick pieces, however, do not catch alight easily and only burn if they are made very hot. Some magnesium is used for making bright lights, as for example, by ships at sea for making signals, but its more important use is in making alloys.

Magnesium compounds are fairly common in the rocks of the Earth's crust (see Fig. 1, p. 8). Some compounds are similar to limestone and whole mountains are made of them, but it is not easy to get the metal from them. In the great " salt " rocks in Germany there is a substance called magnesium chloride. Magnesium can be obtained from this substance in much the same way as aluminium is obtained from its ore. The rock is melted in a cast-iron pot and an electric current passed through. The iron pot forms the cathode. The magnesium is set free at the cathode. It is melted by the heat and floats to the top of the melted rock. It is run off and cast into blocks.

During the last Great War much magnesium was needed for making alloys for aeroplanes. Scientists thought about the magnesium compounds in the sea. In 1941 the first piece of magnesium was made from the sea. Now there are several factories in America where both magnesium and bromine are made and magnesium has also been obtained from the sea near England. The magnesium compounds are changed into a very pure form of magnesium chloride and then the metal obtained in the way we have described.

Magnesium alloys have many uses. Almost all these alloys contain aluminium, and some also contain zinc or manganese. They are very light in weight (about two-thirds the weight of aluminium) and can be shaped easily. They are used chiefly for parts of aeroplanes and motor-car engines.

We now turn to another material in the sea. Many years ago men used to burn wood and put the white ashes in pots of water. The water dissolved a substance, something like soda, from the ash. They called this substance "pot-ash." We know now that potash is a compound formed from the metal which we call potassium. (We do not often see the metal.) Potassium compounds are very important. All plants need potassium compounds in order to grow well. A farmer often spreads potassium compounds on his fields as a fertilizer to help his crops to grow. Many tons of potassium compounds are needed, all over the world, for such purposes.

The seas contain potassium compounds. These compounds, however, are so like ordinary salt that it is difficult to separate them. If we put some sea water in a pan and boil away the water we obtain a mixture of salt, potassium compounds, and other materials. Now suppose we heat the water *very slowly*, so that the water boils away very gradually. First the salt settles as a solid at the bottom of the pan, then the potassium compounds, and then the magnesium compounds. But we should get only 3½ lbs. of all kinds of compounds from 100 lbs. of sea water. The cost of heating the water, especially as it would have to be done so carefully, would be more than the value of the materials obtained. In some parts of the world there are salt-water lakes which contain more dissolved substances than ordinary sea water. Some are in America; another is the Dead Sea. 100 lbs. of water of the Dead Sea contain 30 lbs. (not 3½ lbs.) of dissolved materials. So, by using this water, we should get much more material (including potassium compounds) than from ordinary sea water. The compounds might be worth the cost of getting them.

In the last few years big amounts of potassium compounds have been obtained from the Dead Sea. Water is pumped from the Sea into big hollows made in the

(*By courtesy of Palestine Potash Ltd.*)

Potash from the Dead Sea. Loading the dried material into trucks.

ground. The sun slowly evaporates the water, and, by careful arrangement, the potassium compounds can be obtained separately. Great amounts of "potash" for use on farms are obtained in this way.

The sea contains very small amounts of other useful materials. Men have tried to get gold, for example, from the sea. But, as we have already noted, the amounts of the materials are so small that it is cheaper to get them from ores in the rocks. One may say, perhaps, when most of the ores have been used up, men will try to make greater use of the "treasures" in the sea.

SCIENCE IN THE MODERN WORLD

TREASURES FROM THE EARTH

This book tells the story of man's use of the rocks, and describes mining and the making of useful materials from the products, explaining some of the simple chemistry of the processes. Building materials, coal, oil, the commoner metals, jewels and finally the sea as a source of materials are discussed.

OTHER BOOKS IN THE SERIES

The Air Around Us deals with wind, rain and weather; breathing; burning; gases; pumps; balloons and aeroplanes.

The Earth On Which We Live deals with the size and shape of the earth; the seasons; maps; the soil and the seas.

Machines and Engines explains simple mechanical contrivances and engines, natural sources of power, electricity and atomic power.

The Wonders of Light proceeds from simple ideas to lamps, shadows, and straight-line propagation. Mirrors, lenses and optical instruments and colour, x-rays and the photo-electric cell are also examined.

Electricity discusses the essential principles of electric cells and circuits, electric lighting and heating, electroplating and electromagnets.

Fire and Heat starts with a discussion of the nature of combustion, fire and flame, and the common types of fuel. The methods of transmission of heat are examined as well as man's use of fire as a source of heat and power.

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